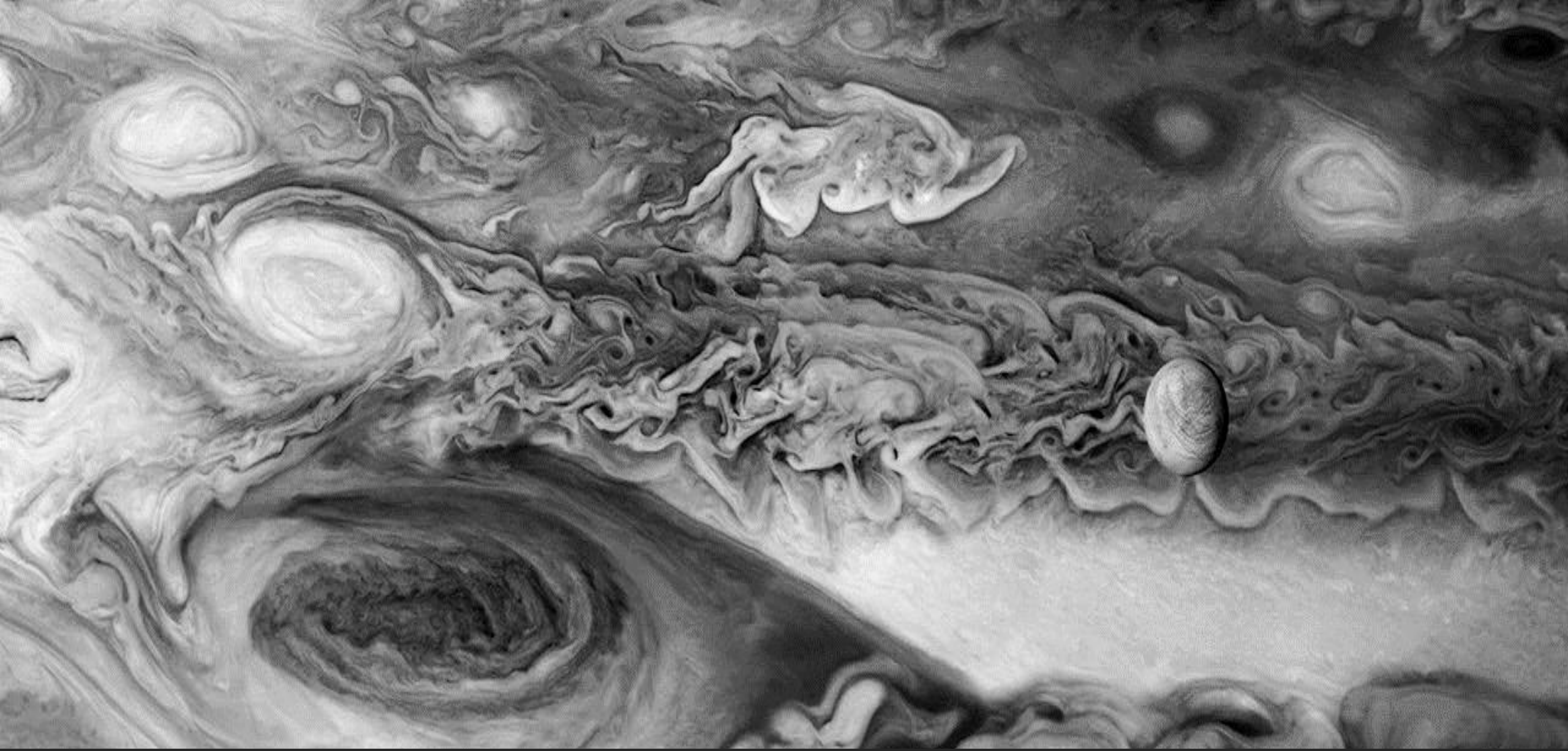


STAF: a new standard for science systems engineering of flagship missions

Sara Susca, Laura Jones-Wilson
Jet Propulsion Laboratory, California Institute of Technology

EUROPA

Problem Statement

Mission Science Goal

Mission Science Objectives

Negotiated with NASA HQ

?

Guidance from NASA Engineering Handbook/ IEEE SE standards are Systems-Engineering-centric, and can be awkward to apply to a science requirements flowdown

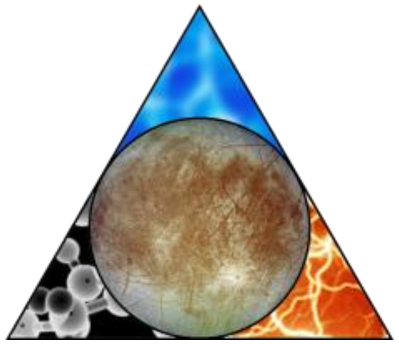
Instruments

Selected by NASA HQ

The *Planned* Europa Clipper Mission

Mission Science Goal

Explore Europa to Investigate its Habitability



Mission Science Objectives

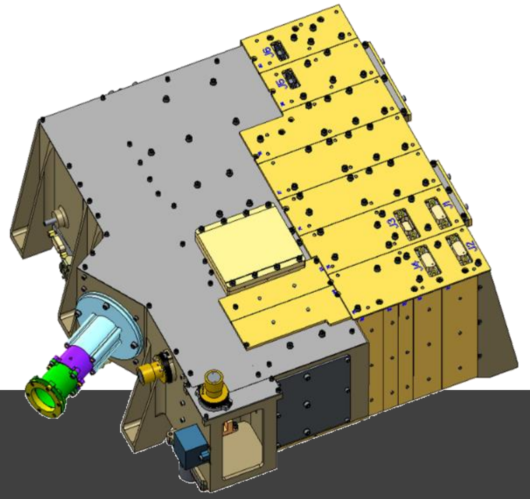
Constrain the average thickness of the ice shell, and the average thickness and salinity of the ocean, each to +/-50%.

?

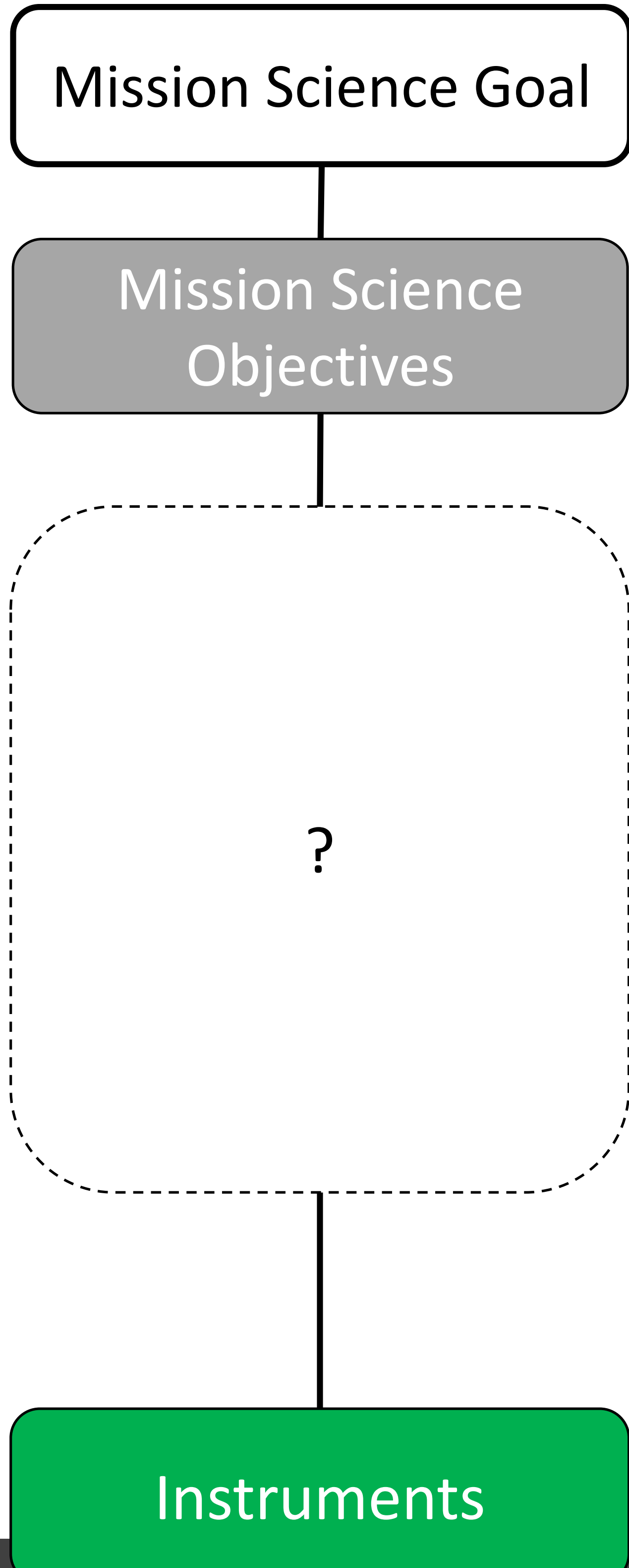
Instruments

Europa Instruments:

1. EIS NAC
2. EIS WAC
3. E-THEMIS
4. Europa-UVS
5. ICEMAG
6. MASPEX
7. MISE
8. PIMS
9. REASON
10. SUDA

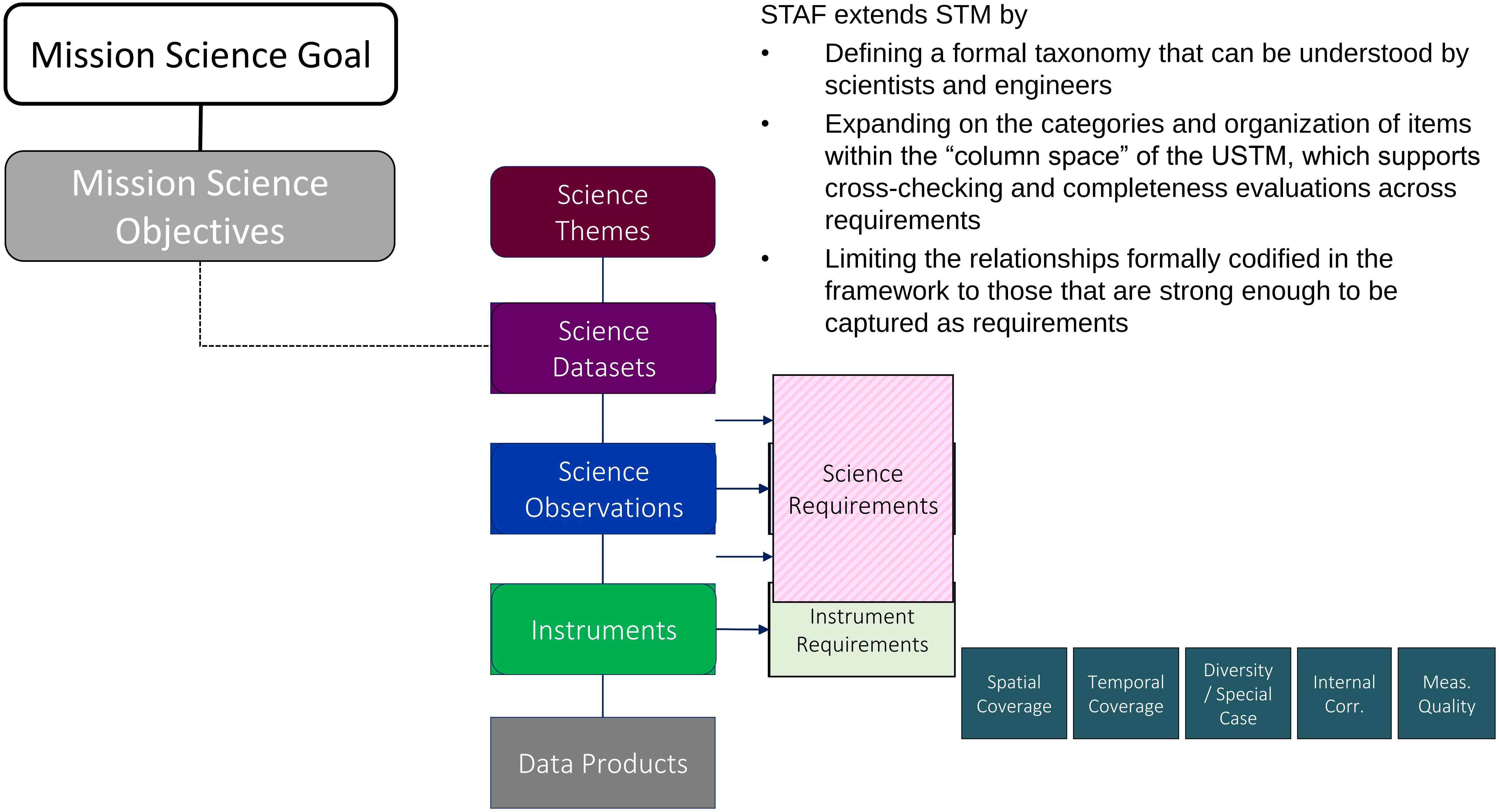


Science Traceability MATRIX



Science Objectives	Measurement Objectives	Measurement Requirements	Instruments	Instrument Requirements	Data Products
Science Objective 1	Measurement Objective 3	• Requirement 1 • Requirement 2	Inst 1	• Requirement A • Requirement B	DP 1
Science Objective 2	Measurement Objective 1	• Requirement 3 • Requirement 4 • Requirement 5 • Requirement 6	Inst 2, 3	• Requirement C • Requirement D	DP 2,3
	Measurement Objective 2	• Requirement 1 • Requirement 4 • Requirement 7	Inst 1,3	• Requirement E • Requirement F • Requirement G	DP 4,5,6
	Measurement Objective 3	• Requirement 1 • Requirement 8	Inst 4	• Requirement H	DP 7
	Measurement Objective 4	• Requirement 9	Inst 2,4	• Requirement I	DP 8, 9

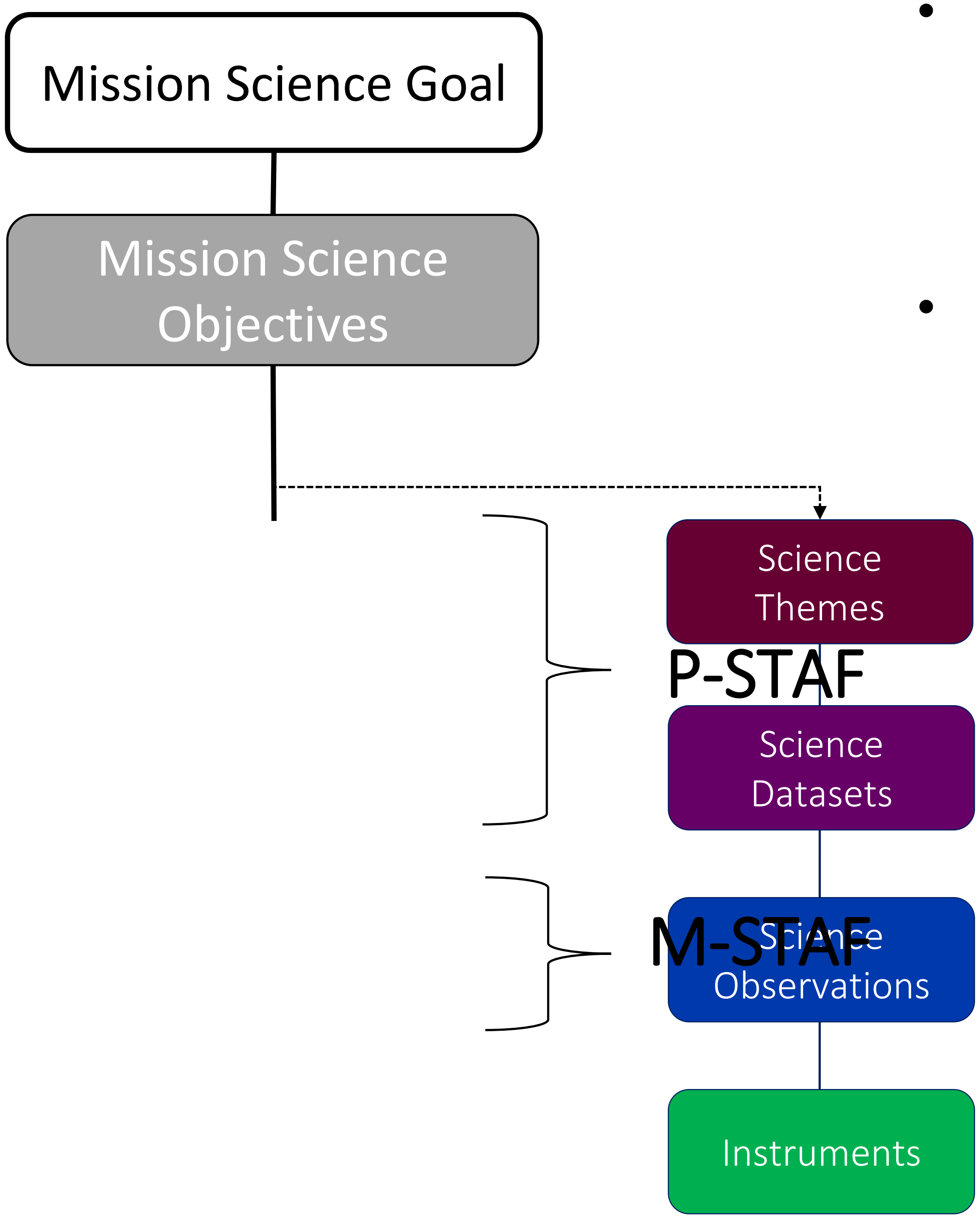
Science Traceability and Alignment Framework



STAF extends STM by

- Defining a formal taxonomy that can be understood by scientists and engineers
- Expanding on the categories and organization of items within the “column space” of the USTM, which supports cross-checking and completeness evaluations across requirements
- Limiting the relationships formally codified in the framework to those that are strong enough to be captured as requirements

Science Traceability and Alignment Framework



- STAF offers:
  - Traceability
  - Completeness
  - Consistency across instruments
- STAF provides efficiency in:
  - Prioritizing
  - Tour analysis
  - Mission robustness analysis

STAF Taxonomy Example

Mission Science Goal

Mission Science Objectives

*Constrain the average **thickness of the ice shell**, and the average **thickness and salinity of the ocean**, each to +/-50%.*

Science Themes

This L1 can be decomposed into two themes
Ocean Properties
Ice shell Properties

Science Datasets

If an **instrument** contributes to a Science Theme it will have a corresponding **Science Dataset**.

Example: Ocean Properties **Plasma Dataset**

Science Observations

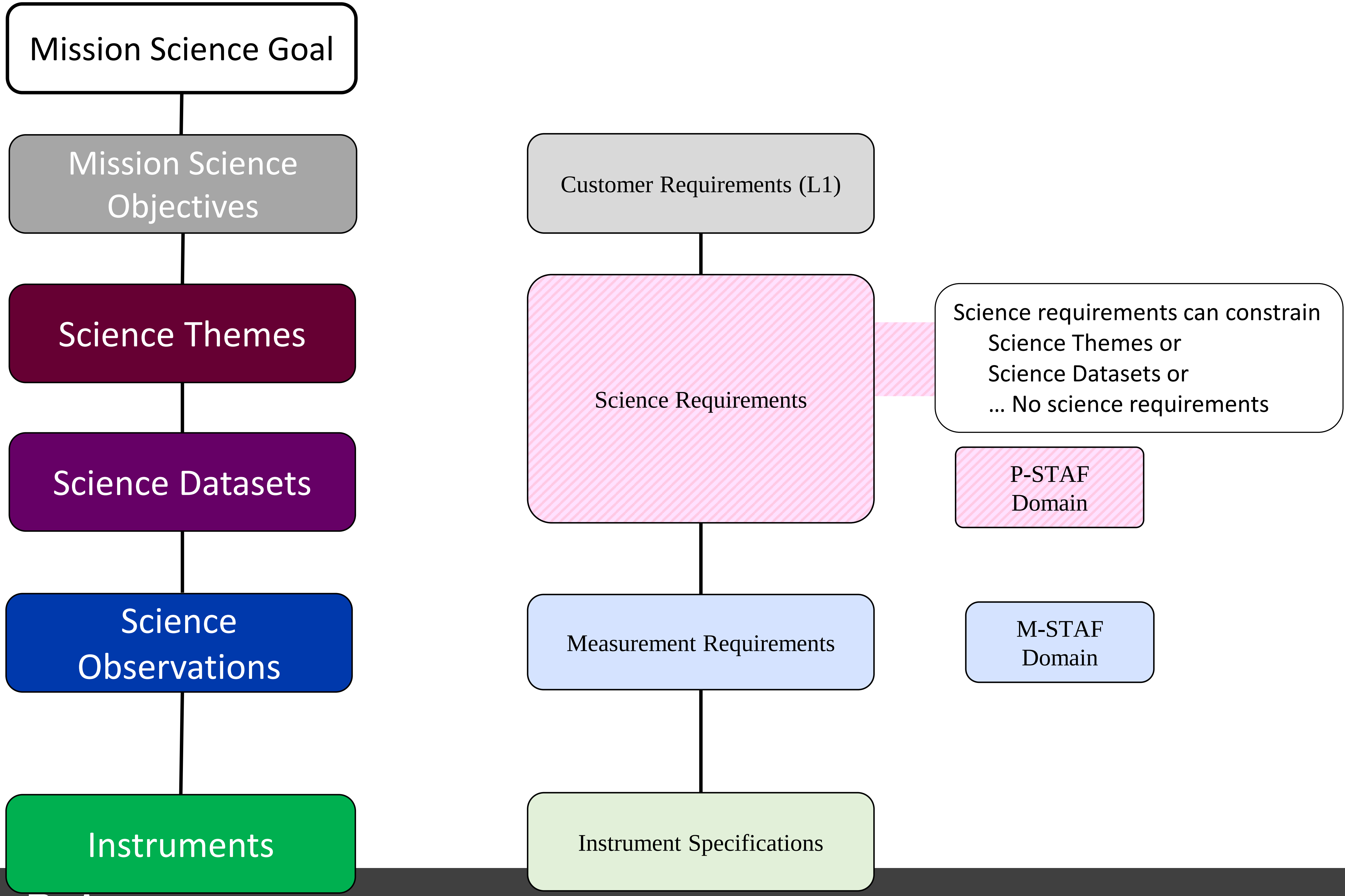
Observations of the particular instrument that feed into a Science Dataset.

Example: **Ions Observations, Electrons Observations**

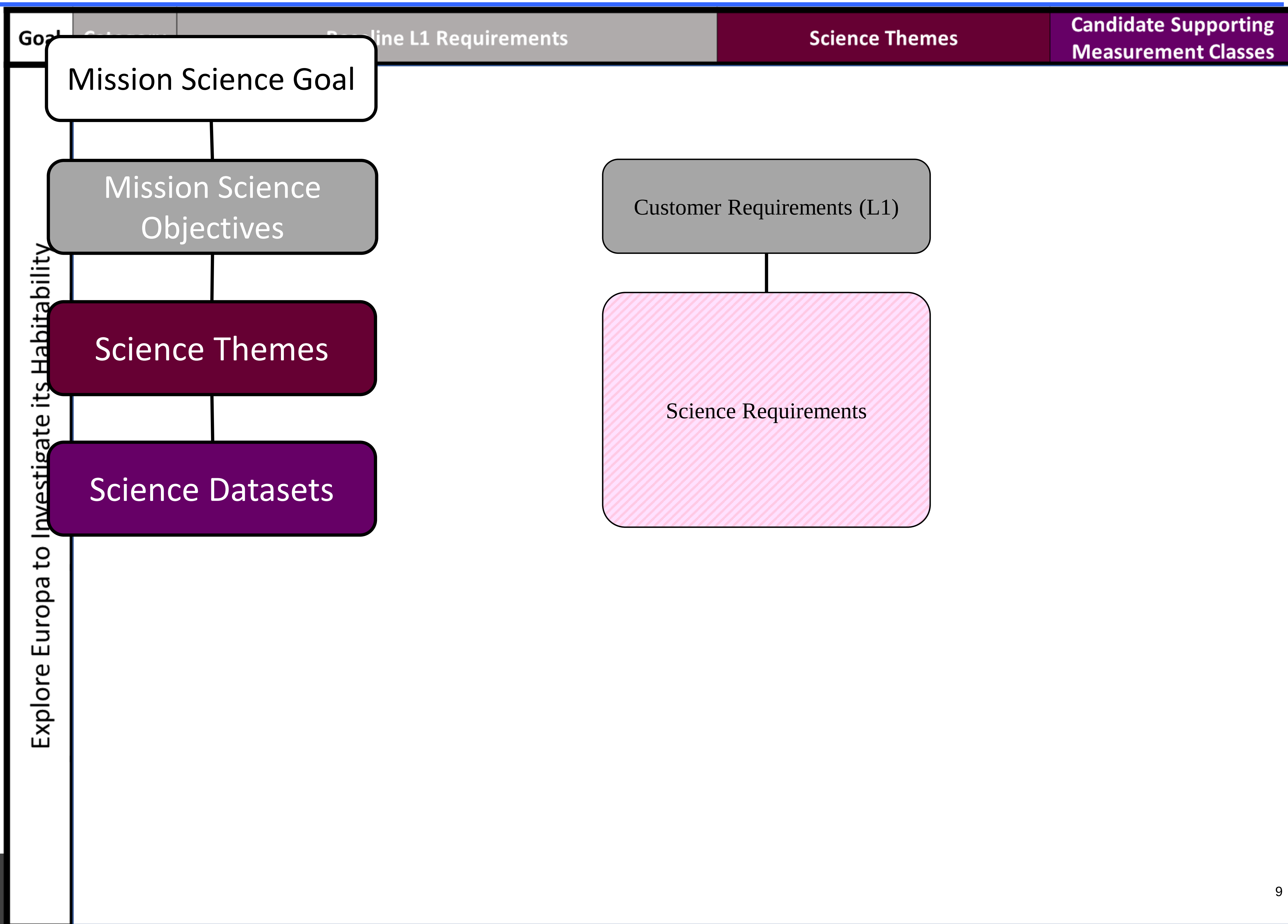
Instruments

PIMS

STAF and the Science Requirements Flowdown



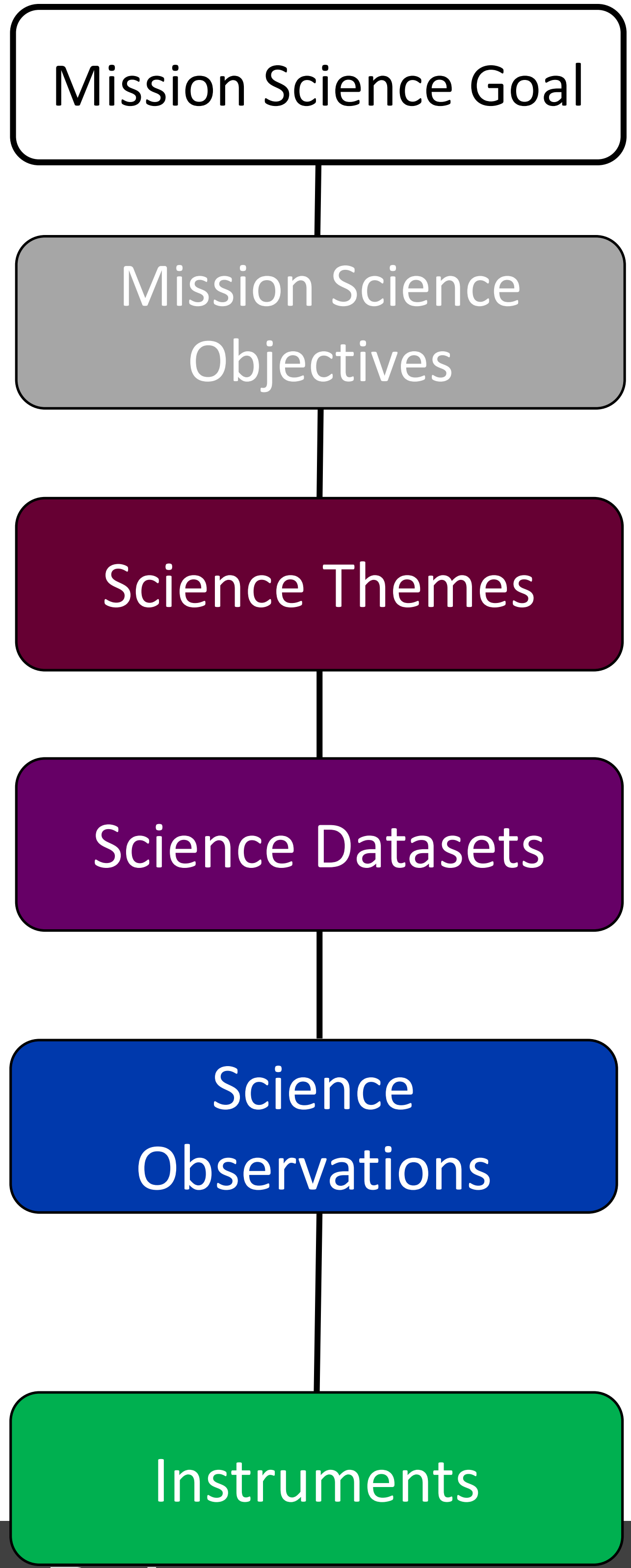
P-STAF: Linking L1s to the Science Datasets

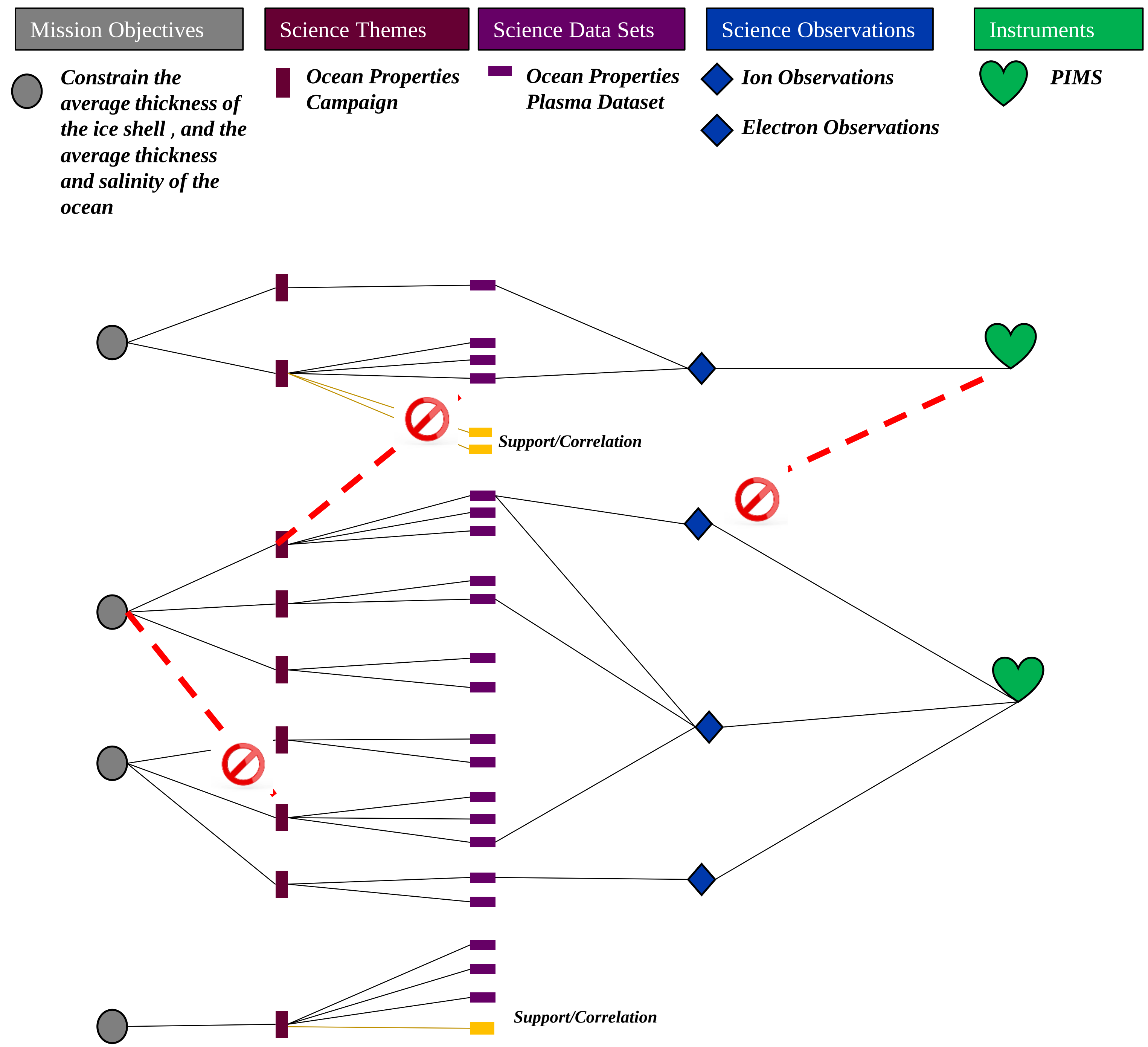


P-STAF Matrix and Traceability

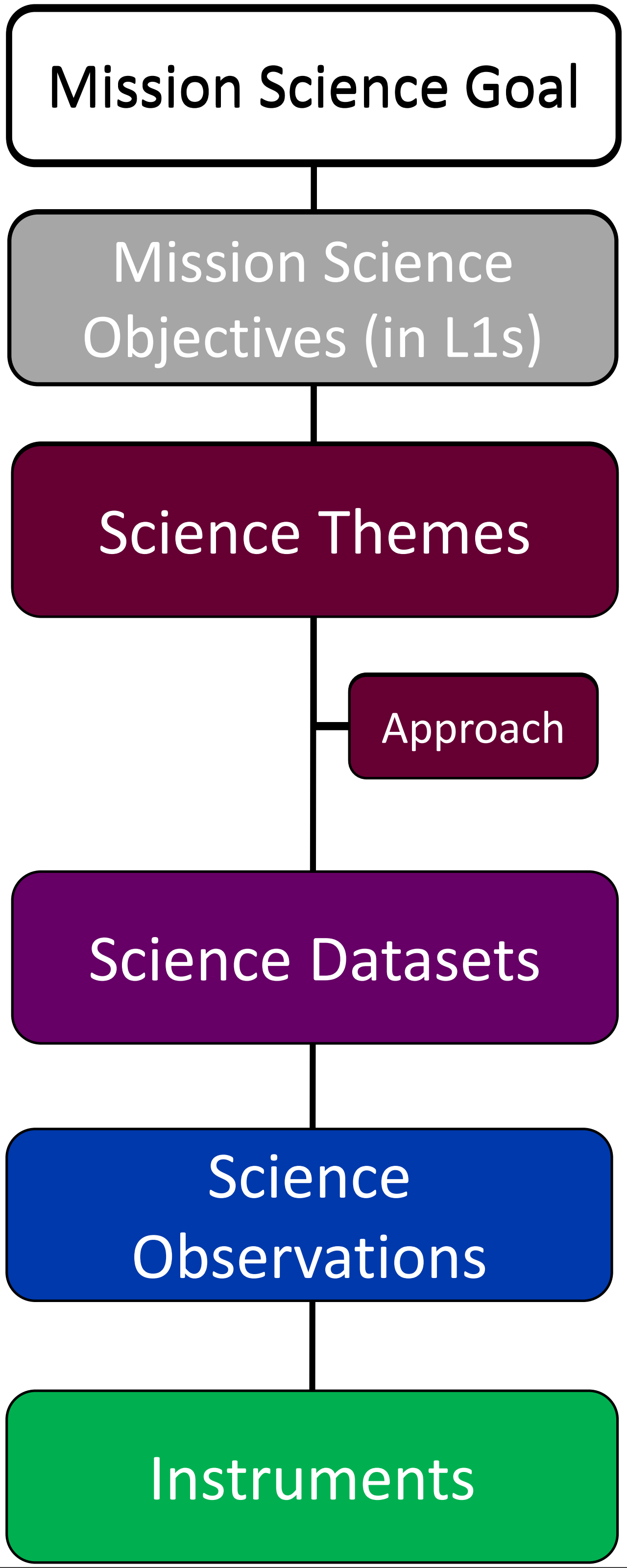
Goal	Category	Baseline L1 Requirements	Science Themes	Candidate Supporting Measurement Classes
Explore Europa to Investigate its Habitability	Ice Shell & Ocean	Map the vertical subsurface structure beneath ≥50 globally distributed landforms to ≥3 km depth [, to understand the distribution of subsurface water and processes of surface-ice-ocean exchange].	Deep Subsurface Exchange	Radar (with Visible Support)
			Shallow Subsurface Exchange	Radar (with Visible Support), Thermal
		Constrain the average thickness of the ice shell, and the average thickness and salinity of the ocean, each to +/-50%.	Ice Shell Properties	Gravity (with Visible and Radar Support), Magnetic, Plasma, Radar (with Visible Support), Visible
			Ocean Properties	Gravity (with Visible and Radar Support), Magnetic, Plasma, Visible
	Composition	Create a compositional map at ≤10 km spatial scale, covering ≥70% of the surface[, to identify the composition and distribution of surface materials].	Global-Scale Compositional Surface Mapping	Infrared, IMS, Ultraviolet, Visible
		Characterize the composition of ≥50 globally distributed landforms, at ≤300 m spatial scale [, to identify non-ice surface constituents including any carbon-containing compounds].	Landform Composition	IMS, Infrared, NMS, Radar (with Visible support), Ultraviolet, Visible
		Characterize the composition and sources of volatiles, particulates, and plasma, with sensitivity sufficient to identify the signatures of non-ice materials including any carbon-containing compounds, in globally distributed ions of the atmosphere and local space environment.	Atmospheric Composition	IMS, NMS, Magnetic, Plasma, Radar, Ultraviolet
			Space Environment Composition	IMS, NMS, Magnetic, Plasma, Ultraviolet
	Geology	Produce a controlled photomosaic map of ≥80% of the surface at ≤100-m spatial scale[, to map the global distribution and relationships of geologic landforms].	Global-Scale Surface Mapping	Thermal, Visible
		Characterize the surface at ≤25-m spatial scale, and measure topography at ≤15-m vertical precision, across ≥50 globally distributed landforms[, to identify their morphology and diversity].	Landform Geology	Radar (with Visible support), Thermal, Visible
		Characterize the surface at ~1-m scale to determine surface properties, for ≥40 sites each ≥2 km x 4 km .	Local-Scale Surface Properties	Infrared, Radar, Thermal, Visible
	Recent Activity	Search for and characterize any current activity, notably plumes and thermal anomalies, in regions that are globally distributed.	Active Plume Search	Thermal, Ultraviolet, Visible
			Inferred Plume Evidence	IMS, Infrared, Magnetic, NMS, Plasma, Radar Thermal, Visible
			Surface Thermal Anomaly Search	Infrared, Thermal
			Surface Activity Evidence	Infrared, NMS, Thermal, Visible

Creating an Analyzable Network





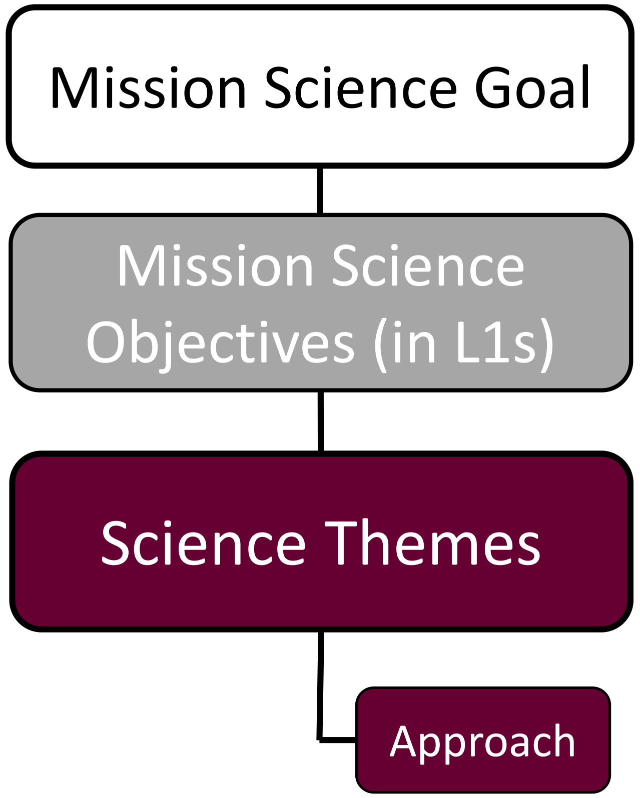
Science Traceability and Alignment Framework Taxonomy



Different Ways to Address a Specific Theme

e.g. Morphology; Topography

Approaches as They Relate to Themes



Developed by the science management team to better understand how instrument groupings approach a given science theme

Goal	Category	L1	Science Themes	Threshold Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding
			Ocean Properties	Induction, K2, Static Global Shape, H2 (+K2)
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes

How Approaches and Themes Roll Up

Mission Science Goal
Mission Science Objectives (in L1s)
Science Themes
Approach

Mission Science Goal

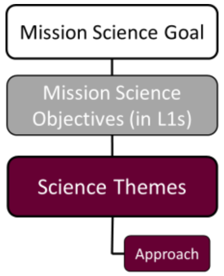
Mission Science Objectives (in L1s)

Goal | Category | L1 | Science Themes | Threshold Approaches

Goal	Category	L1	Science Themes	Baseline Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding, Shape and Gravity
			Ocean Properties	Induction, Shape and Gravity
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	Morphology, Roughness and Permittivity
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes

Science Themes	Threshold Approaches
Deep Subsurface Exchange	Sounding
Shallow Subsurface Structure	Sounding
Ice Shell Properties	Induction, Sounding
Ocean Properties	Induction, K2, Static Global Shape, H2 (+K2)
Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
Landform Composition	Complex Species and Units, Simple Species and Units
Atmospheric Composition	Complex Volatile Species, Simple Volatile Species, Particulates
Space Environment Composition	Complex Volatile Species, Simple Volatile Species, Particulates
Global Surface Mapping	Morphology
Landform Geology	Morphology, Topography
Local-Scale Surface Properties	
Remote Plume Search and Characterization	Volatiles, Particulates
In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
Surface Thermal Anomaly Search	Thermal Emission
Surface Activity Evidence	Deposits, Surface Changes

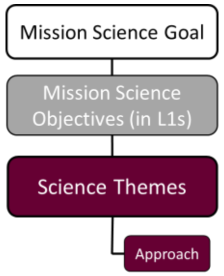
How Approaches and Themes Roll Up



AND Relationship
OR Relationship
Enhancing Relationship

Goal	Category	L1	Science Themes	Baseline Approaches	Science Themes	Threshold Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding	Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding	Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding, Shape and Gravity	Ice Shell Properties	Induction, Sounding
			Ocean Properties	Induction, Shape and Gravity	Ocean Properties	Induction, K2, Static Global Shape, H2 (+K2)
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units	Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units	Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates	Atmospheric Composition	Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Plasma, Complex Volatile Species, Simple Volatile Species, Particulates	Space Environment Composition	Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology	Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography	Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	Morphology, Roughness and Permittivity	Local-Scale Surface Properties	
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates	Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma	In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission	Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes	Surface Activity Evidence	Deposits, Surface Changes

How Approaches and Themes Roll Up



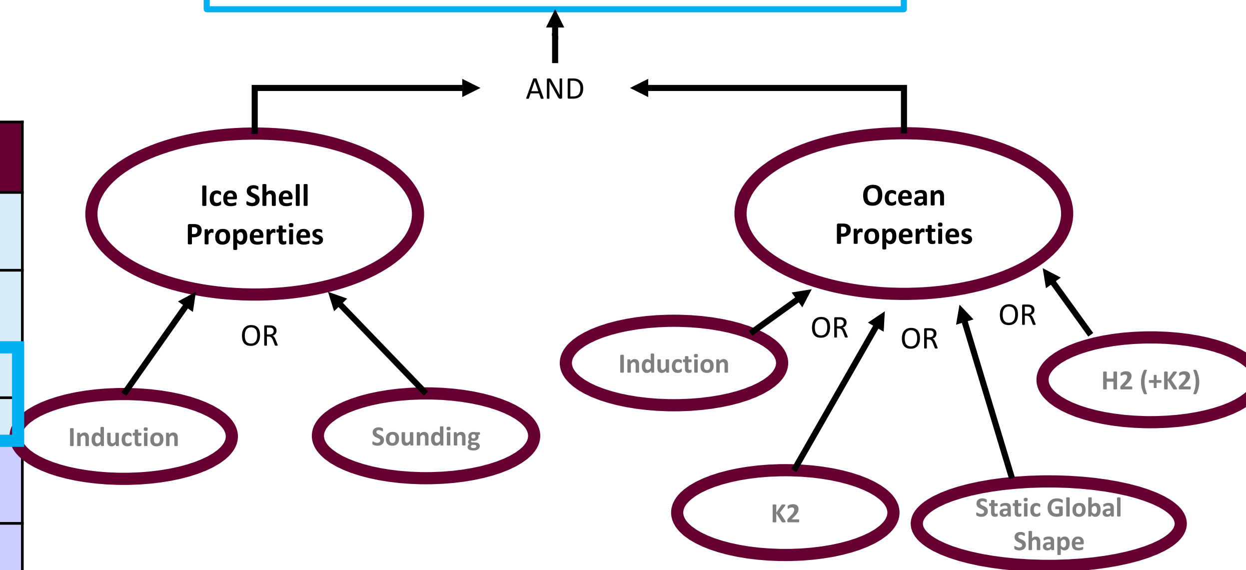
AND Relationship

OR Relationship

Enhancing Relationship

Goal	Category	L1	Science Themes	Threshold Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding
			Ocean Properties	Induction, K2, Static Global Shape, H2 (+K2)
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes

TH L1: Confirm the presence of a subsurface ocean, and constrain whether the ice shell is in a “thin” (several km) or “thick” (10s km) regime.



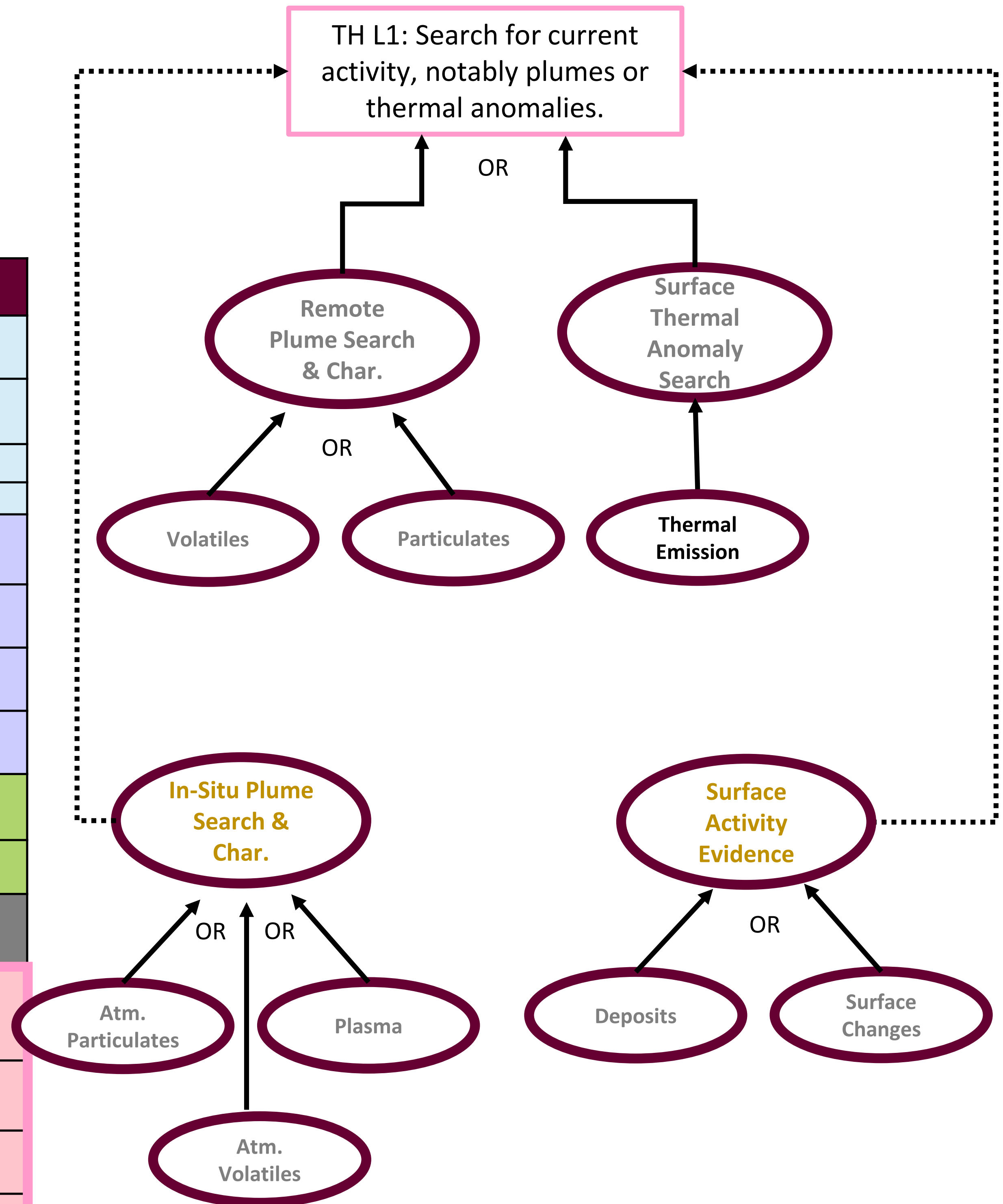
How Approaches and Themes Roll Up

How do we do this using numbers so a spreadsheet can easily interpret it?

Mission Science Goal
Mission Science Objectives (in L1s)
Science Themes
Approach

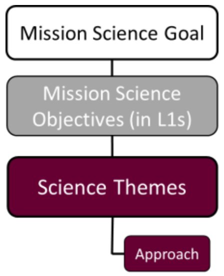
AND Relationship
OR Relationship
Enhancing Relationship

Goal	Category	L1	Science Themes	Threshold Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding
			Ocean Properties	Induction, K2, Static Global Shape, H2 (+K2)
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes



How Approaches and Themes Roll Up

How do we do this using numbers so a spreadsheet can easily interpret it?

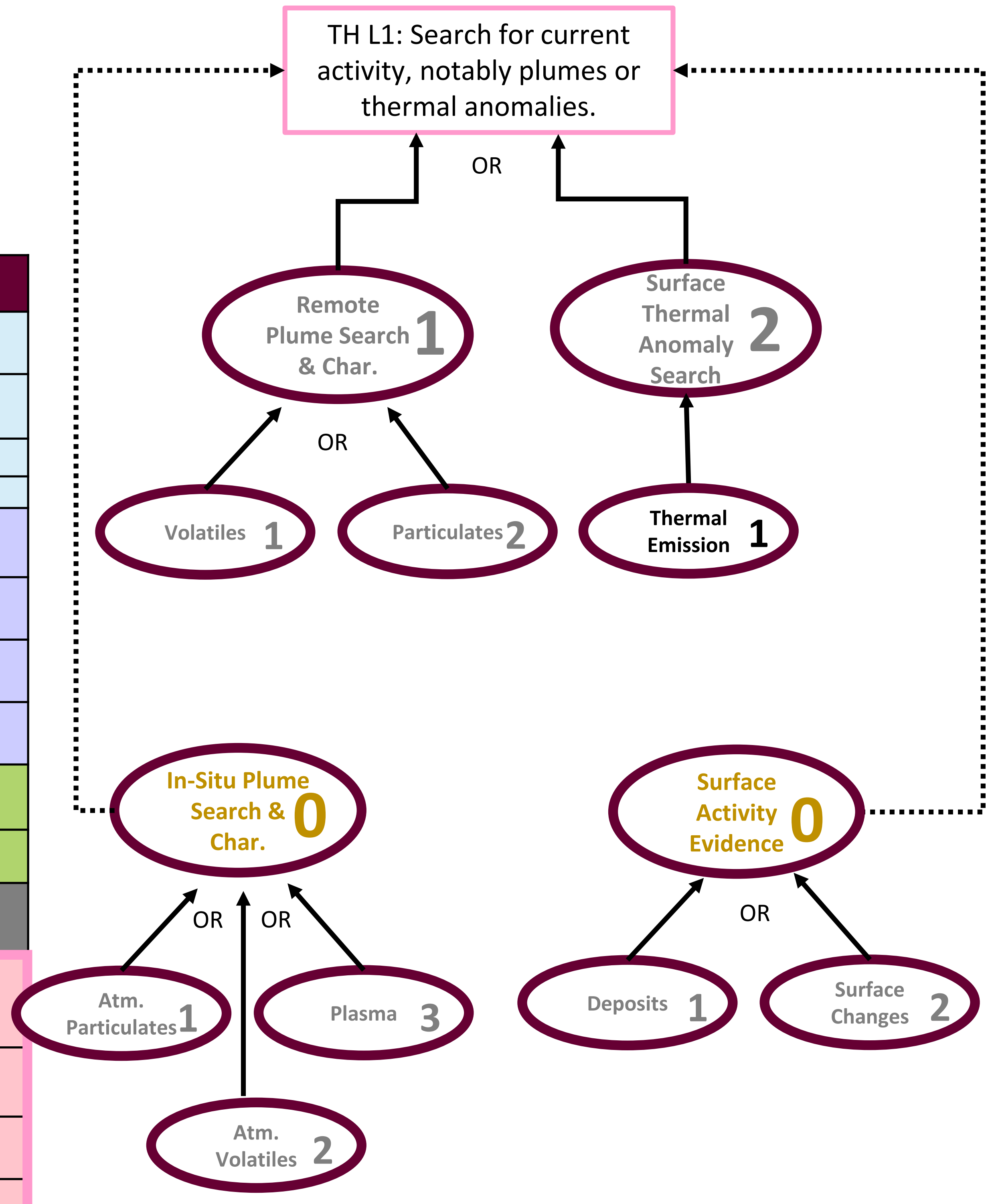


AND Relationship: Same number, not zero

OR Relationship, Different number, not zero

Enhancing Relationship, Zero

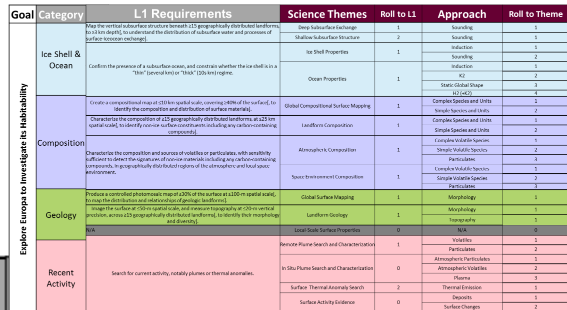
Goal	Category	L1	Science Themes	Threshold Approaches
Explore Europa to Investigate its Habitability	Ice Shell & Ocean		Deep Subsurface Exchange	Sounding
			Shallow Subsurface Structure	Sounding
			Ice Shell Properties	Induction, Sounding
			Ocean Properties	Induction, K2, Static Global Shape, H2 (+K2)
	Composition		Global Compositional Surface Mapping	Complex Species and Units, Simple Species and Units
			Landform Composition	Complex Species and Units, Simple Species and Units
			Atmospheric Composition	Complex Volatile Species, Simple Volatile Species, Particulates
			Space Environment Composition	Complex Volatile Species, Simple Volatile Species, Particulates
	Geology		Global Surface Mapping	Morphology
			Landform Geology	Morphology, Topography
			Local-Scale Surface Properties	
	Recent Activity		Remote Plume Search and Characterization	Volatiles, Particulates
			In Situ Plume Search and Characterization	Atmospheric Particulates, Atmospheric Volatiles, Plasma
			Surface Thermal Anomaly Search	Thermal Emission
			Surface Activity Evidence	Deposits, Surface Changes



How Approaches and Themes Roll Up

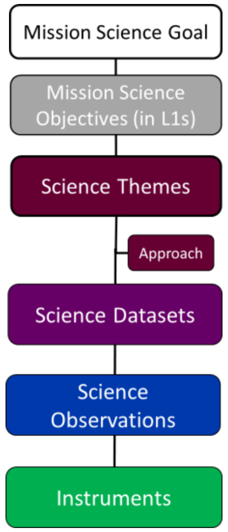
How do we do this using numbers so a spreadsheet can easily interpret it?

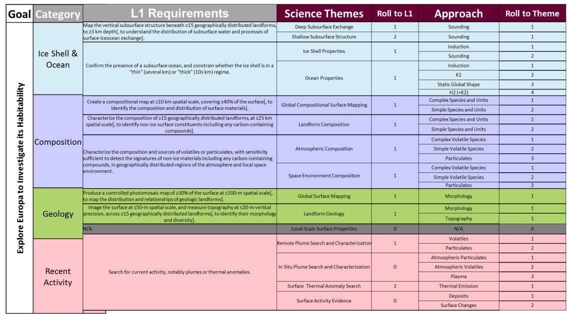
Mission Science Goal
Mission Science Objectives (in L1s)
Science Themes
Approach

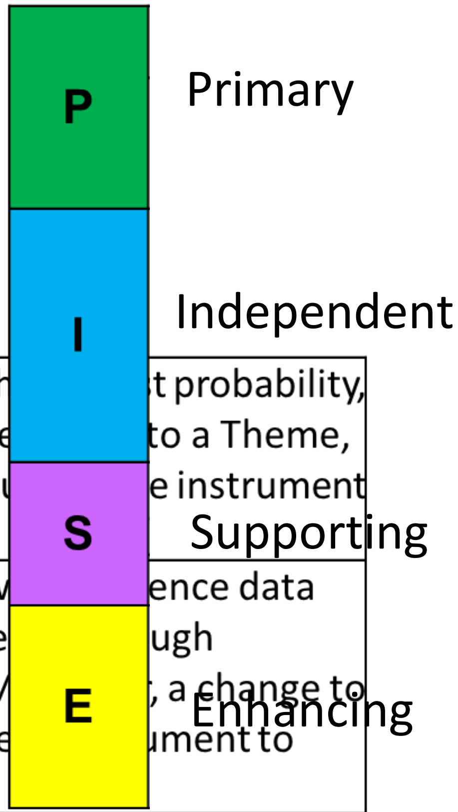


Goal	Category	L1 Requirements	Science Themes	Roll to L1	Approach	Roll to Theme
Explore Europa to Investigate its Habitability	Ice Shell & Ocean	Map the vertical subsurface structure beneath ≥15 geographically distributed landforms, to ≥3 km depth[, to understand the distribution of subsurface water and processes of surface-iceocean exchange].	Deep Subsurface Exchange	1	Sounding	1
			Shallow Subsurface Structure	2	Sounding	1
		Confirm the presence of a subsurface ocean, and constrain whether the ice shell is in a “thin” (several km) or “thick” (10s km) regime.	Ice Shell Properties	1	Induction	1
					Sounding	2
			Ocean Properties	1	Induction	1
					K2	2
					Static Global Shape	3
					H2 (+K2)	4
	Composition	Create a compositional map at ≤10 km spatial scale, covering ≥40% of the surface[, to identify the composition and distribution of surface materials].	Global Compositional Surface Mapping	1	Complex Species and Units	1
					Simple Species and Units	2
		Characterize the composition of ≥15 geographically distributed landforms, at ≤25 km spatial scale[, to identify non-ice surface constituents including any carbon-containing compounds].	Landform Composition	1	Complex Species and Units	1
					Simple Species and Units	2
		Characterize the composition and sources of volatiles or particulates, with sensitivity sufficient to detect the signatures of non-ice materials including any carbon-containing compounds, in geographically distributed regions of the atmosphere and local space environment.	Atmospheric Composition	1	Complex Volatile Species	1
					Simple Volatile Species	2
					Particulates	3
			Space Environment Composition	1	Complex Volatile Species	1
					Simple Volatile Species	2
					Particulates	3
	Geology	Produce a controlled photomosaic map of ≥30% of the surface at ≤100-m spatial scale[, to map the distribution and relationships of geologic landforms].	Global Surface Mapping	1	Morphology	1
		Image the surface at ≤50-m spatial scale, and measure topography at ≤20-m vertical precision, across ≥15 geographically distributed landforms[, to identify their morphology and diversity].	Landform Geology	1	Morphology	1
					Topography	1
		N/A	Local-Scale Surface Properties	0	N/A	0
	Recent Activity	Search for current activity, notably plumes or thermal anomalies.	Remote Plume Search and Characterization	1	Volatiles	1
					Particulates	2
			In Situ Plume Search and Characterization	0	Atmospheric Particulates	1
					Atmospheric Volatiles	2
					Plasma	3
			Surface Thermal Anomaly Search	2	Thermal Emission	1
			Surface Activity Evidence	0	Deposits	1
					Surface Changes	2

Approaching the P-STAF Matrix



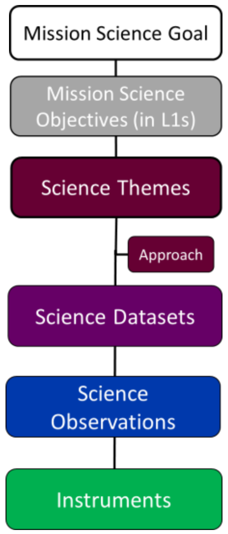




P	**Primary.** The instrument that can provide, most robustly and with … t probability, the science data necessary to fully achieve a given approach as pe… to a Theme, in the nominal mission plan. In indicated instances, data from a Su… e instrument also may be required.
I	**Independent.** An instrument (other than a Primary instrument) w… ence data can enable a given approach as pertinent to a Theme to be achie… ugh potentially less robustly than from a Primary instrument's data. M… , a change to the mission plan may be required for the data from an Independe… ument to achieve the approach in question.
S	**Supportive .** Said of an instrument whose science data is required to enable data from the Primary instrument to fully achieve a given approach as pertinent to a Theme.
E	**Enhancing-:** Said of an instrument whose data is expected to further enhance the overall science return beyond that of data from a Primary or Independent instrument in achieving a given approach as pertinent to a Theme. There is no dependency implied between a Primary or Independent instrument and an Enhancing instrument.

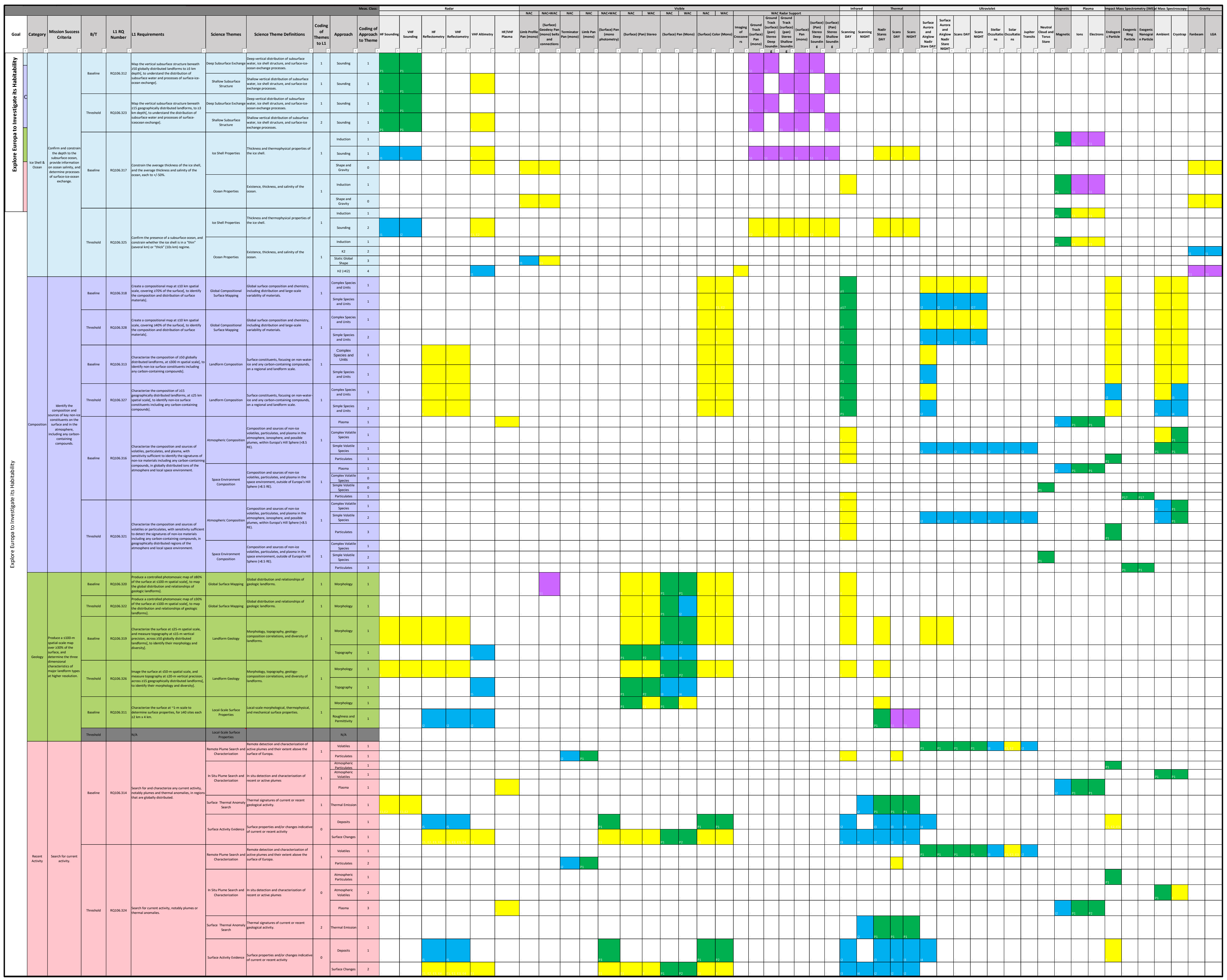
Identified ways to contribute:

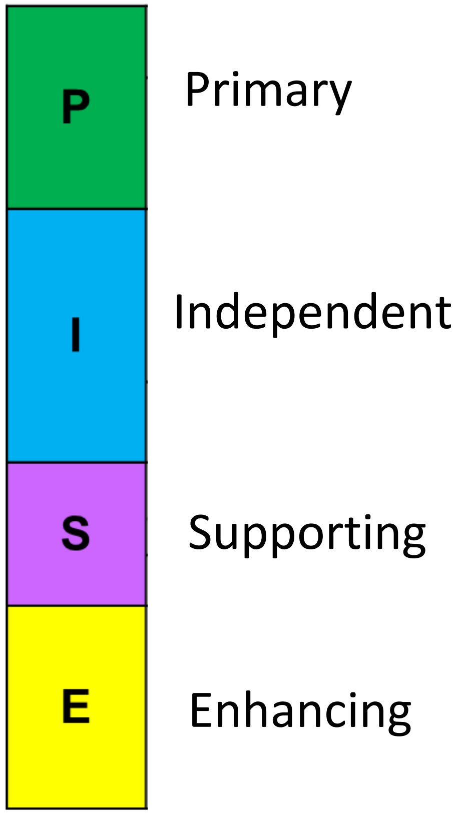
Raw P-STAF Matrix



Science Observations by Measurement Class

L1, Science Theme, Approach





Rolling Up: Baseline Mapping

Queries to the network:

- Which L1s have single point of failures?
- What's the minimum set (instrument or observation) necessary to meet an L1 or a group of L1s?
- In how many independent ways can each L1 be met?
- How much energy and data each L1 needs?
- Etc…

			REASON		EIS			MISE	E-THEMIS	UVS	ICEMAG	PIMS	SUDA	MASPEX	GRAVITY
			Radar		Visible										
L1 Requirements	Science Themes	Science Theme Definitions	VHF	HF	NAC	WAC	WAC Radar support	Infrared	Thermal	UV	Magnetic	Plasma	IMS	NMS	Gravity
Map the vertical subsurface structure beneath ≥50 globally distributed landforms to ≥3 km depth[, to understand the distribution of subsurface water and processes of surface-ice-ocean exchange].	Deep Subsurface Exchange	Deep vertical distribution of subsurface water, ice shell structure, and surface-ice-ocean exchange processes.	1000	1000			40								
	Shallow Subsurface Structure	Shallow vertical distribution of subsurface water, ice shell structure, and surface-ice exchange processes.	1001	1000			40								
Constrain the average thickness of the ice shel and salinity of the ocean, each to +/-50%.												20			0.0002
												20			0.0002
Create a compositional map at ≤10 km spatial surface[, to identify the composition and distri													2	4	
Characterize the composition of ≥50 globally d ≤300 m spatial scale[, to identify non-ice surfa carbon-containing compounds].													2	4	
Characterize the composition and sources of v plasma, with sensitivity sufficient to identify th materials including any carbon-containing com distributed ions of the atmosphere and local sp												000	1000	3001	
												000	2000		
Produce a controlled photomosaic map of ≥80 spatial scale[, to map the global distribution an landforms].															
Characterize the surface at ≤25-m spatial scale ≤15-m vertical precision, across ≥50 globally di identify their morphology and diversity].															
Characterize the surface at ~1-m scale to determine surface properties, for ≥40 sites each ≥2 km x 4 km.	Local-Scale Surface Properties	Local-scale morphological, thermophysical, and mechanical surface properties.	200	100	2000	2			1021						
Search for and characterize any current activity, notably plumes and thermal anomalies, in regions that are globally distributed.	Remote Plume Search and Characterization	Remote detection and characterization of active plumes and their extent above the surface of Europa.			1100			1	1	4201					
	In Situ Plume Search and Characterization	In situ detection and characterization of recent or active plumes	0.0001	0.0001							0.01	0.2	1000	2000	
	Surface Thermal Anomaly Search	Thermal signatures of current or recent geological activity.	1	1				100	3000						
	Surface Activity Evidence	Surface properties and/or changes indicative of current or recent activity	102	101	3003	3003		300	600	100			1		

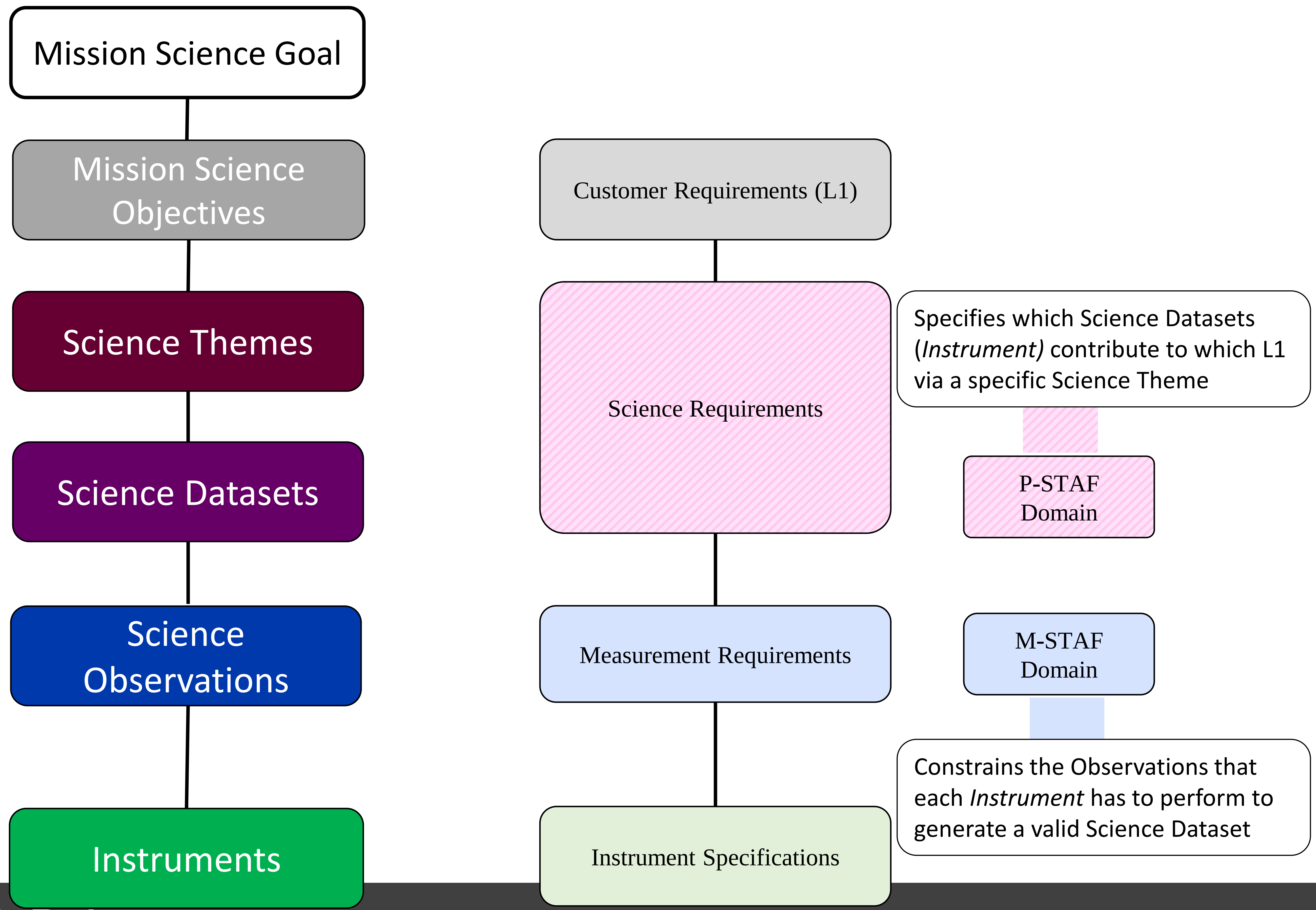
Useful to see the highest-tier designation for each instrument, and which instruments contribute in which ways to a theme

This roll-up is not a perfect way to see the "OR" relationships or to see the many paths to achieving the L1 requirements

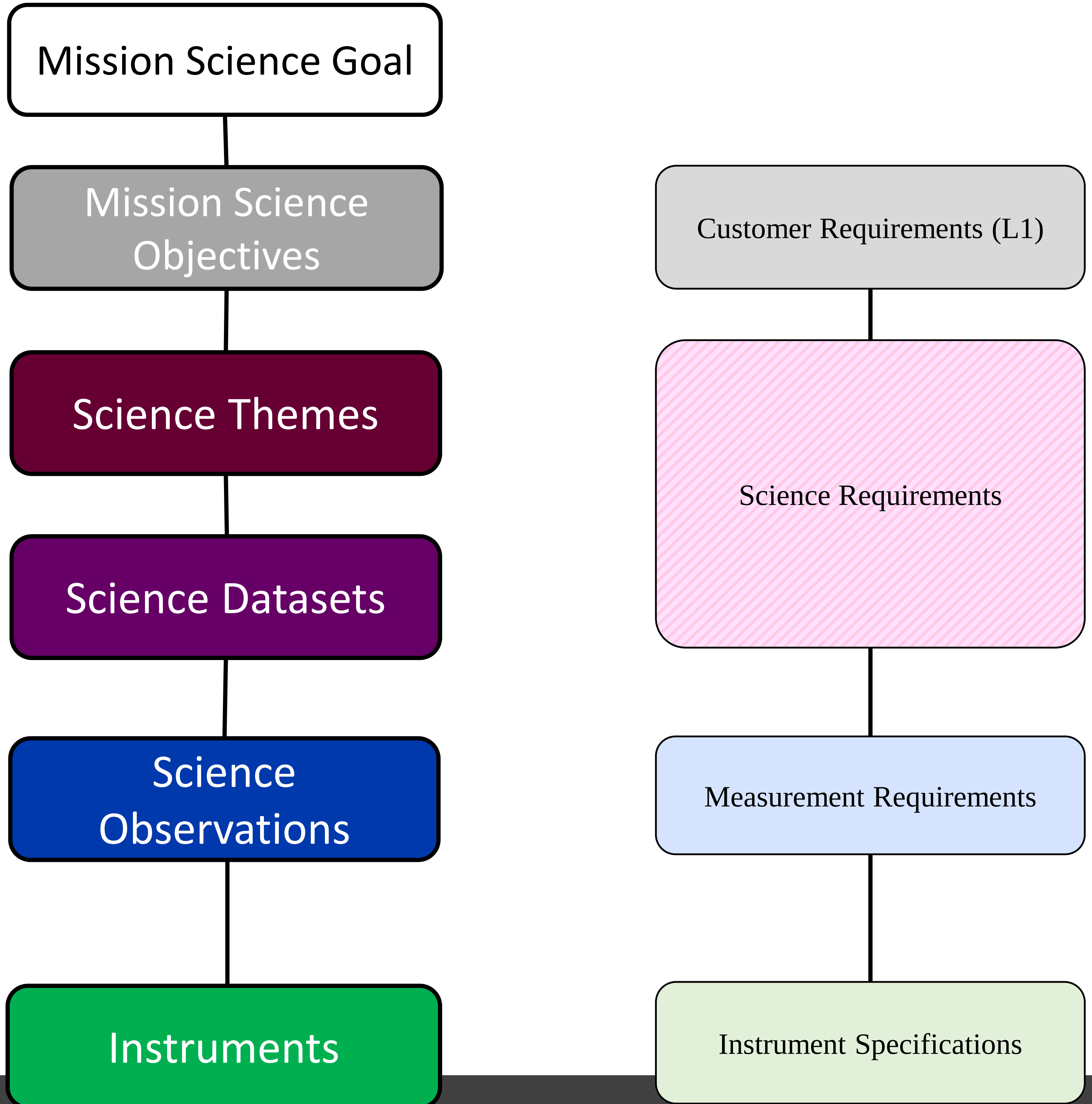
Rolling Up: Threshold Mapping

			REASON		EIS			MISE	E-THEMIS	UVS	ICEMAG	PIMS	SUDA	MASPEX	GRAVITY
			Radar		Visible										
L1 Requirements	**Science Themes**	**Science Theme Definitions**	**VHF**	**HF**	**NAC**	**WAC**	**WAC Radar support**	**Infrared**	**Thermal**	**UV**	**Magnetic**	**Plasma**	**IMS**	**NMS**	**Gravity**
Map the vertical subsurface structure beneath ≥15 geographically distributed landforms, to ≥3 km depth[, to understand the distribution of subsurface water and processes of surface-iceocean exchange].	Deep Subsurface Exchange	Deep vertical distribution of subsurface water, ice shell structure, and surface-ice-ocean exchange processes.	1000	2000			40								
	Shallow Subsurface Structure	Shallow vertical distribution of subsurface water, ice shell structure, and surface-ice exchange processes.	1001	2000			40								
Confirm the presence of a subsurface ocean, and constrain whether the ice shell is in a "thin" (several km) or "thick" (10s km) regime.	Ice Shell Properties	Thickness and thermophysical properties of the ice shell.	101	200			6		3		1000	2			
	Ocean Properties	Existence, thickness, and salinity of the ocean.	100		101	1	1				1000	2			220
Create a compositional map at ≤10 km spatial scale, covering ≥40% of the surface[, to identify the composition and distribution of surface materials].	Global Compositional Surface Mapping	Global surface composition and chemistry, including distribution and large-scale variability of materials.			2	2		2000		404			2	4	
Characterize the composition of ≥15 geographically distributed landforms, at ≤25 km spatial scale[, to identify non-ice surface constituents including any carbon-containing compounds].	Landform Composition	Surface constituents, focusing on non-water-ice and any carbon-containing compounds, on a regional and landform scale.	2	2	2	2		2000		101			101	301	
Characterize the composition and sources of volatiles or particulates, with sensitivity sufficient to detect the signatures of non-ice materials including any carbon-containing compounds, in geographically distributed regions of the atmosphere and local space environment.	Atmospheric Composition	Composition and sources of non-ice volatiles, particulates, and plasma in the atmosphere, ionosphere, and possiTHe plumes, within Europa's Hill Sphere (<8.5 RE).						3		700			1000	2200	
	Space Environment Composition	Composition and sources of non-ice volatiles, particulates, and plasma in the space environment, outside of Europa's Hill Sphere (>8.5 RE).								1000			2000		
Produce a controlled photomosaic map of ≥30% of the surface at ≤100-m spatial scale[, to map the distribution and relationships of geologic landforms].	Global Surface Mapping	Global distribution and relationships of geologic landforms.			1002	102		1							
Image the surface at ≤50-m spatial scale, and measure topography at ≤20-m vertical precision, across ≥15 geographically distributed landforms[, to identify their morphology and diversity].	Landform Geology	Morphology, topography, geology-composition correlations, and diversity of landforms.	102	3	1002	2102		1	1						
N/A	Local-Scale Surface Properties	Local-scale morphological, thermophysical, and mechanical surface properties.													
Search for current activity, notably plumes or thermal anomalies.	Remote Plume Search and Characterization	Remote detection and characterization of active plumes and their extent above the surface of Europa.			1100				1	4201					
	In Situ Plume Search and Characterization	In situ detection and characterization of recent or active plumes	1								100	2000	1000	1001	
	Surface Thermal Anomaly Search	Thermal signatures of current or recent geological activity.						100	3000						
	Surface Activity Evidence	Surface properties and/or changes indicative of current or recent activity	102	101	3003	3003		300	600	100			1		

From P-STAF to M-STAF



M-STAF: Linking Science Datasets to Measurement Requirements



M-STAF: Linking Science Datasets to Measurement Requirements

Science Dataset		Science Observation			Measurement Requirements							
Science Theme	Meas. Class	Technique	Conditions		Spatial Coverage and Distribution	Temporal Coverage and Distribution	Diversity and Special Case	Internal Correlations	Measurement Quality			
			Cond. A	Cond. B					Qual. A	Qual. B	Qual. C	Qual. D

Science Themes

Science Datasets

Science Observations

Measurement Requirements

M-STAF Matrix: Completeness and Consistency

<table>
<tr><th colspan="14">Instrument Name</th></tr>
<tr><th colspan="3">Science Dataset</th><th colspan="3">Science Observation</th><th colspan="8">Measurement Requirements</th></tr>
<tr><th colspan="2" rowspan="2">Science Theme</th><th rowspan="2">Meas. Class</th><th rowspan="2">Technique</th><th colspan="2">Conditions</th><th rowspan="2">Spatial Coverage and Distribution</th><th rowspan="2">Temporal Coverage and Distribution</th><th rowspan="2">Diversity and Special Case</th><th rowspan="2">Internal Correlations</th><th colspan="4">Measurement Quality</th></tr>
<tr><th>Cond. A</th><th>Cond. B</th><th>Qual. A</th><th>Qual. B</th><th>Qual. C</th><th>Qual. D</th></tr>
<tr><td colspan="3" rowspan="4">Science Dataset 1</td><td>Tech. A</td><td rowspan="7">REQ.003</td><td>REQ.001</td><td rowspan="4">REQ.025</td><td></td><td>REQ.09</td><td>REQ.11</td><td rowspan="7">REQ.10</td><td>REQ.06</td><td>REQ.13, REQ.14</td><td></td></tr>
<tr><td>Tech. B</td><td>REQ.001</td><td rowspan="2"></td><td rowspan="2">REQ.12</td><td>REQ.16</td><td>REQ.15</td><td></td><td></td></tr>
<tr><td>Tech. C</td><td></td><td>REQ.22</td><td></td><td>REQ.027</td><td></td></tr>
<tr><td>Tech. D</td><td></td><td></td><td rowspan="3">REQ.18</td><td>REQ.19</td><td>REQ.031</td><td>REQ.028</td><td></td></tr>
<tr><td colspan="3">Science Dataset 2</td><td>Tech. B</td><td>REQ.001</td><td>REQ.025</td><td>REQ.20</td><td></td><td></td><td></td><td>REQ.026</td></tr>
<tr><td rowspan="2">Science Dataset 3</td><td rowspan="2">Science Dataset 4</td><td rowspan="2">Science Dataset 5</td><td>Tech. A</td><td>REQ.001</td><td rowspan="2">REQ.025</td><td>REQ.21, REQ.24</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Tech. E</td><td></td><td>REQ.17</td><td>REQ.033</td><td>REQ.11</td><td>REQ.032</td><td>REQ.029, REQ.030</td><td></td></tr>
</table>

Measurement Requirements

Missing
Not Applicable
Needs Clarification

Europa-UVS

Science Dataset: Science Campaign	Science Dataset: Meas. Class	Science Observation: Technique	Conditions: Europa Solar Phase Angle	Conditions: Jupiter Solar Phase Angle	Conditions: Altitude @ Meas.	Measurement Requirements: Spatial Coverage and Distribution	Temporal Coverage and Distribution	Diversity and Special Case	Internal Correlations	Measurement Quality: Spectral Bandpass and Resolution	Spatial Resolution at Altitude	Scale Height Resolution	Sensitivity	Sampling
Global-Scale Compositional Surface Mapping	Ultraviolet	Nadir Stares	Day < 90 deg (UVS.026)		< 30,000 km (UVS.036)	70% of surface (UVS.001)	Acquisition over duration of nadir subphase (UVS.018)			<=6 nm btwn at least 150-180 nm ; <=25 nm btwn at least 105-180 nm (UVS.003: UVS.004)	<= 30 km per pixel @30,000 km (UVS.002)		TBR SNR >= 3 per spatial resolution element given a Lyman-alpha albedo of 1% at	Capable of Nyquist sampling (UVS.033)
		Scans	Day < 90 deg (UVS.026)		< 30,000 km (UVS.037)									
		Nadir Stares	Night >= 90 deg (UVS.027)		< 36,000 km (UVS.038)	10% of surface across >= 5 representative regions (UVS.009)	Acquisition over duration of nadir subphase (UVS.018)				<= 100 km per pixel @ 36,000 km (UVS.008)		TBR SNR >= 3 per spatial resolution element given a Lyman-alpha albedo of 1% at 2 deg phase (UVS.034)	
		Scans	Night >= 90 deg (UVS.027)		< 30,000 km (UVS.037)									
Landform Composition	Ultraviolet	Nadir Stares	Day < 90 deg (UVS.026)		< 360 km (UVS.039)	>= 30 representative landforms in >= 11 Europa Panels (UVS.011)		>=1 image with Europa latitude @ CA > 45 deg (UVS.012)		<= 6 nm btwn at least 150-180 nm ; <= 25 nm btwn at least 105-180 nm (UVS.003: UVS.004)	<= 1 km per pixel @ 360 km (UVS.010)		TBR SNR >= 3 per spatial resolution element given a Lyman-alpha albedo of 1% at 2 deg phase (UVS.034)	Capable of Nyquist sampling (UVS.033)
Atmospheric Composition / Space Environment Composition	Ultraviolet	Nadir Stares			< 390,000 km (UVS.030)	1 image in each Europa Panel and each local solar time bin (UVS.017)	>= 1 image in each combo of Europa Panel and local solar time bin; acquisition over duration of nadir subphase (UVS.017; UVS.018)			<= 2 nm btwn at least 60-180 nm (UVS.005)	TBR [30] km per pixel @ TBR [30,000] km (UVS.024)			Capable of Nyquist sampling (UVS.033)
		Scans			< 390,000 km (UVS.030)	>= 6 per flyby, distributed evenly on inbound and outbound (UVS.019)	<= 2 hours apart, distributed over >= 6 hours; distributed over >= TBR [18] months (UVS.021, UVS.031)				TBR [500] km per pixel @ TBR [165,000] km (UVS.023)		TBR SNR >= 3 per spatial resolution element given an emission brightness of 0.1 Rayleighs near 130 nm (UVS.035)	
		Stellar Occ				>= TBR [100] with at least 1 in every Europa Panel (UVS.014)						<= 50 km (UVS.013)		Continuous sampling from 400 km to Europa surface
		Solar Occ				>= 1 (UVS.015)								
		Jupiter Transit		< 120 deg (UVS.029)	< 350,000 km (UVS.028)	>= 10 (UVS.016)								
		Neutral Cloud and Torus Stare			>= 500,000 km (UVS.032)	>= 1 per orbit for >= 20 orbits (UVS.022)								
		Nadir Stares			< 390,000 km (UVS.030)	1 image in each Europa Panel and each local solar time bin	>= 1 image in each combo of Europa Panel and local solar time bin; acquisition over duration of nadir				TBR [30] km per pixel @ TBR [30,000] km (UVS.024)			

Requirements Templates

Europa-UVS														
Science Dataset		**Science Observation**				**Measurement Requirements**								
			Conditions							**Measurement Quality**				
Science Campaign	**Meas. Class**	**Technique**	**Europa Solar Phase Angle**	**Jupiter Solar Phase Angle**	**Altitude @ Meas.**	**Spatial Coverage and Distribution**	**Temporal Coverage and Distribution**	**Diversity and Special Case**	**Internal Correlations**	**Spectral Bandpass and Resolution**	**Spatial Resolution at Altitude**	**Scale Height Resolution**	**Sensitivity**	**Sampling**
Global-Scale Compositional Surface Mapping	Ultraviolet	Nadir Stares	Day < 90 deg (UVS.026)		< 30,000 km (UVS.036)	70% of surface (UVS.001)	Acquisition over duration of nadir subphase (UVS.018)			<=6 nm btwn at least 150-180 nm ; <=25 nm btwn at least 105-180 nm (UVS.003: UVS.004)	<= 30 km per pixel @30,000 km (UVS.002)		TBR SNR >= 3 per spatial resolution element given a Lyman-alpha albedo of 1% at	Capable of Nyquist sampling (UVS.033)
		Scans	Day < 90 deg (UVS.026)		< 30,000 km (UVS.037)									
		Nadir Stares	Night >= 90 deg (UVS.027)		< 36,000 km (UVS.038)	10% of surface across >= 5 representative regions (UVS.009)	Acquisition over duration of nadir subphase (UVS.018)				<= 100 km per pixel @ 36,000 km (UVS.008)		TBR SNR >= 3 per spatial resolution element given a Lyman-alpha albedo of 1% at 2 deg phase (UVS.034)	
		Scans	Night >= 90 deg (UVS.027)		< 30,000 km (UVS.037)									

Condition Requirement Template:

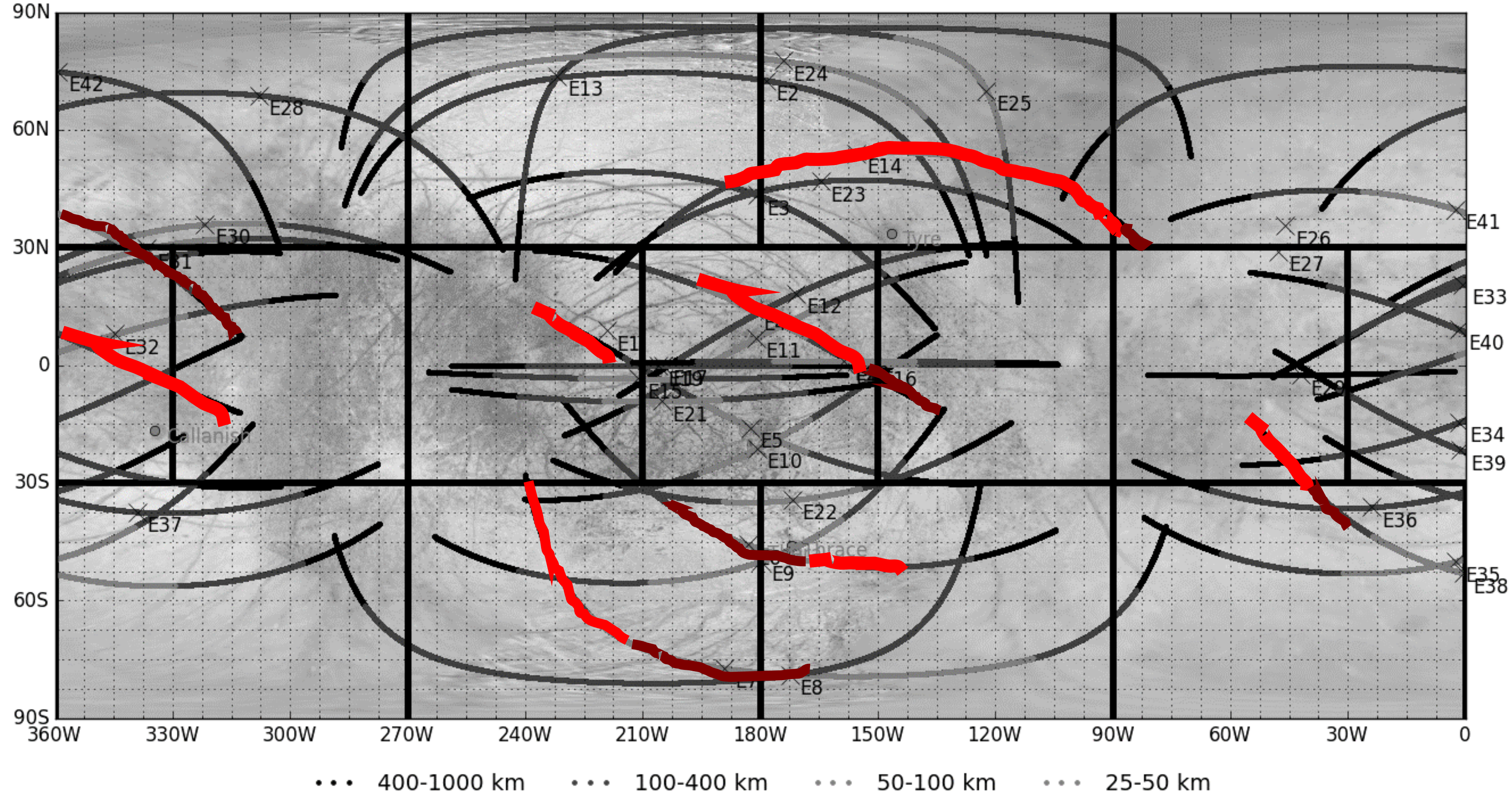
For the [Science Dataset(s)], the [Science Observation] shall occur when the [**Condition** Type] is... [**Condition** Value].

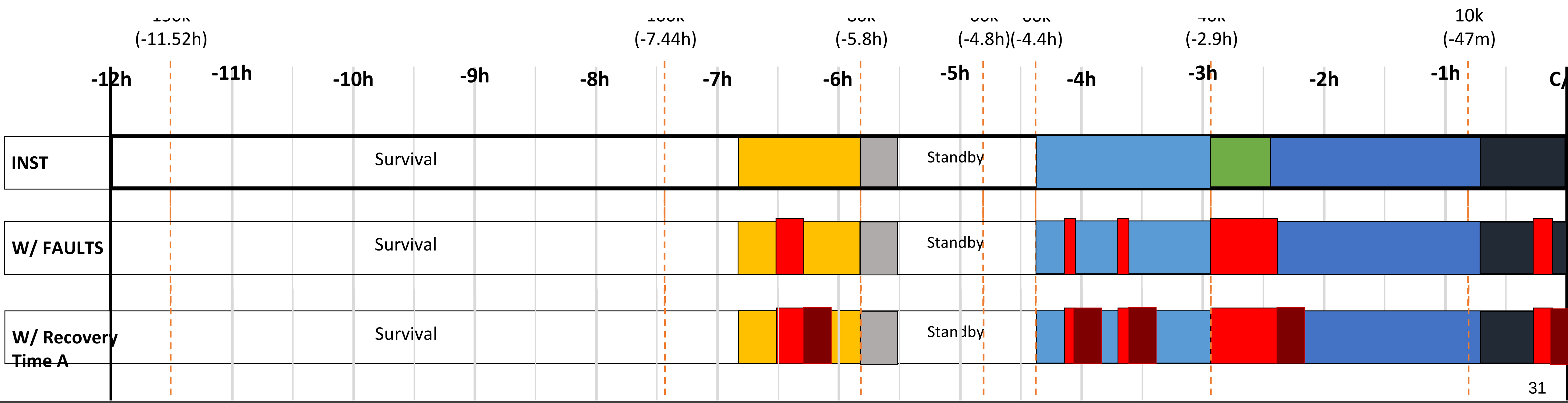
For Global-Scale Compositional Surface Mapping Ultraviolet dataset**,** all dayside nadir stares shall occur when the ***Europa solar phase angle*** is less than ***90 degrees***. (UVS.026)

Using the P-STAF and M-STAF to Address Project Needs

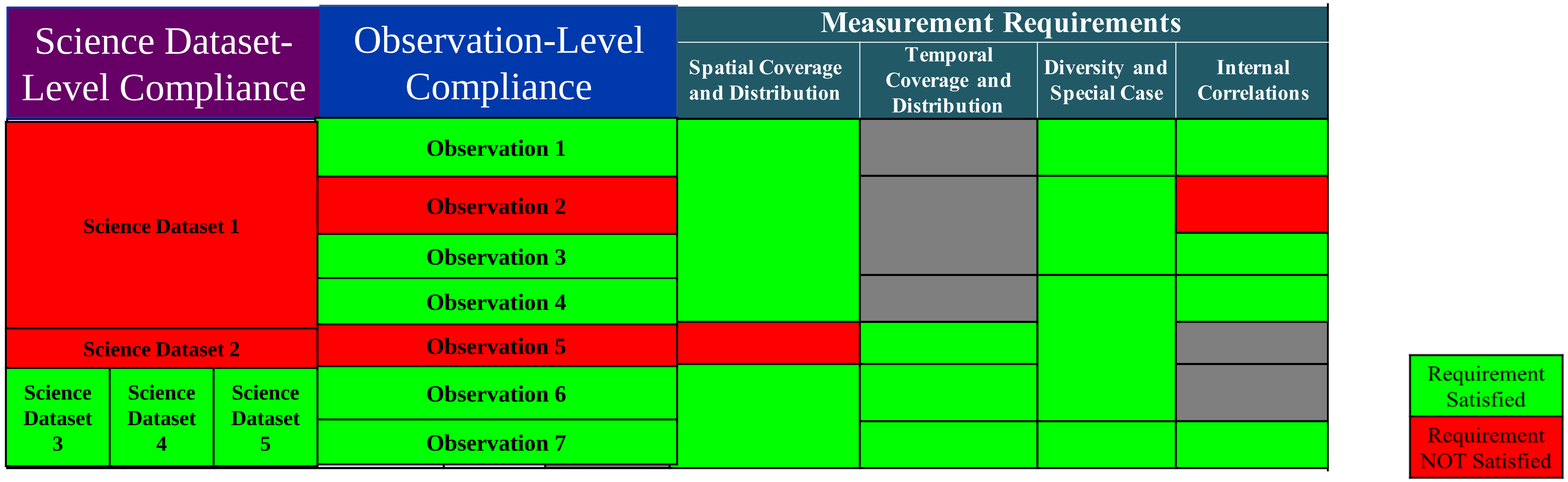
Science Dataset		Science Observation			Measurement Requirements							
Science Campaign	Meas. Class	Technique	Conditions: Cond. A	Conditions: Cond. B	Spatial Coverage and Distribution	Temporal Coverage and Distribution	Diversity and Special Case	Internal Correlations	Measurement Quality: Qual. A	Measurement Quality: Qual. B	Measurement Quality: Qual. C	Measurement Quality: Qual. D
Science Dataset 1		Tech. A	REQ.003	REQ.001	REQ.025		REQ.09	REQ.11	REQ.10	REQ.06	REQ.13, REQ.14	
		Tech. B		REQ.001			REQ.12	REQ.16		REQ.15		
		Tech. C						REQ.22			REQ.027	
		Tech. D					REQ.18	REQ.19		REQ.031	REQ.028	
Science Dataset 2		Tech. B	REQ.003	REQ.001	REQ.025	REQ.20			REQ.10			REQ.026
Science Dataset 3 / Science Dataset 4 / Science Dataset 5		Tech. A	REQ.003	REQ.001	REQ.025	REQ.21, REQ.24			REQ.10			
		Tech. E				REQ.17	REQ.033	REQ.11		REQ.032	REQ.029, REQ.030	

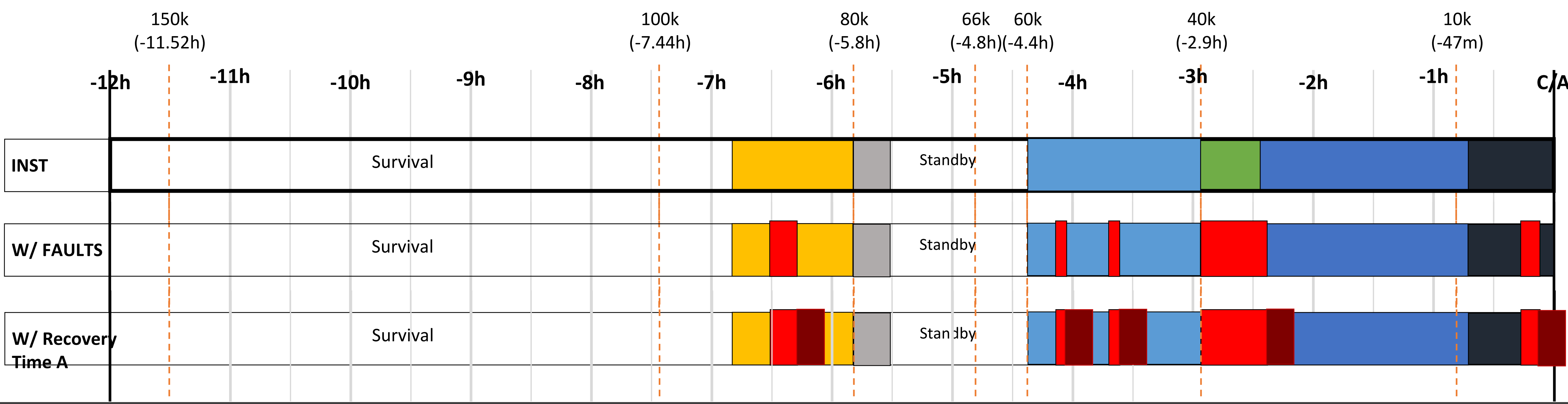
Tour Analysis and Mission Robustness



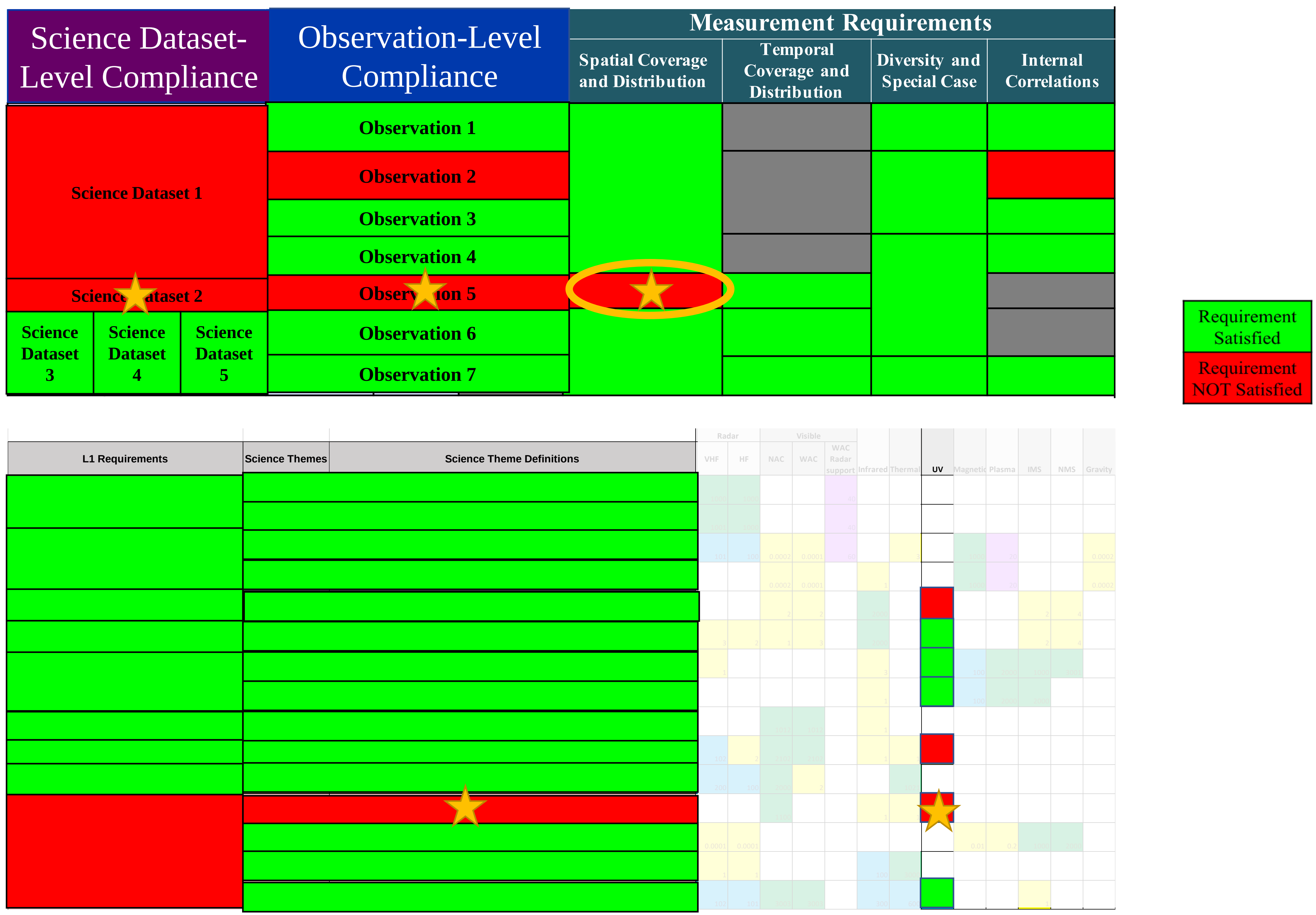


Assessment of Impacts at the Measurement Level





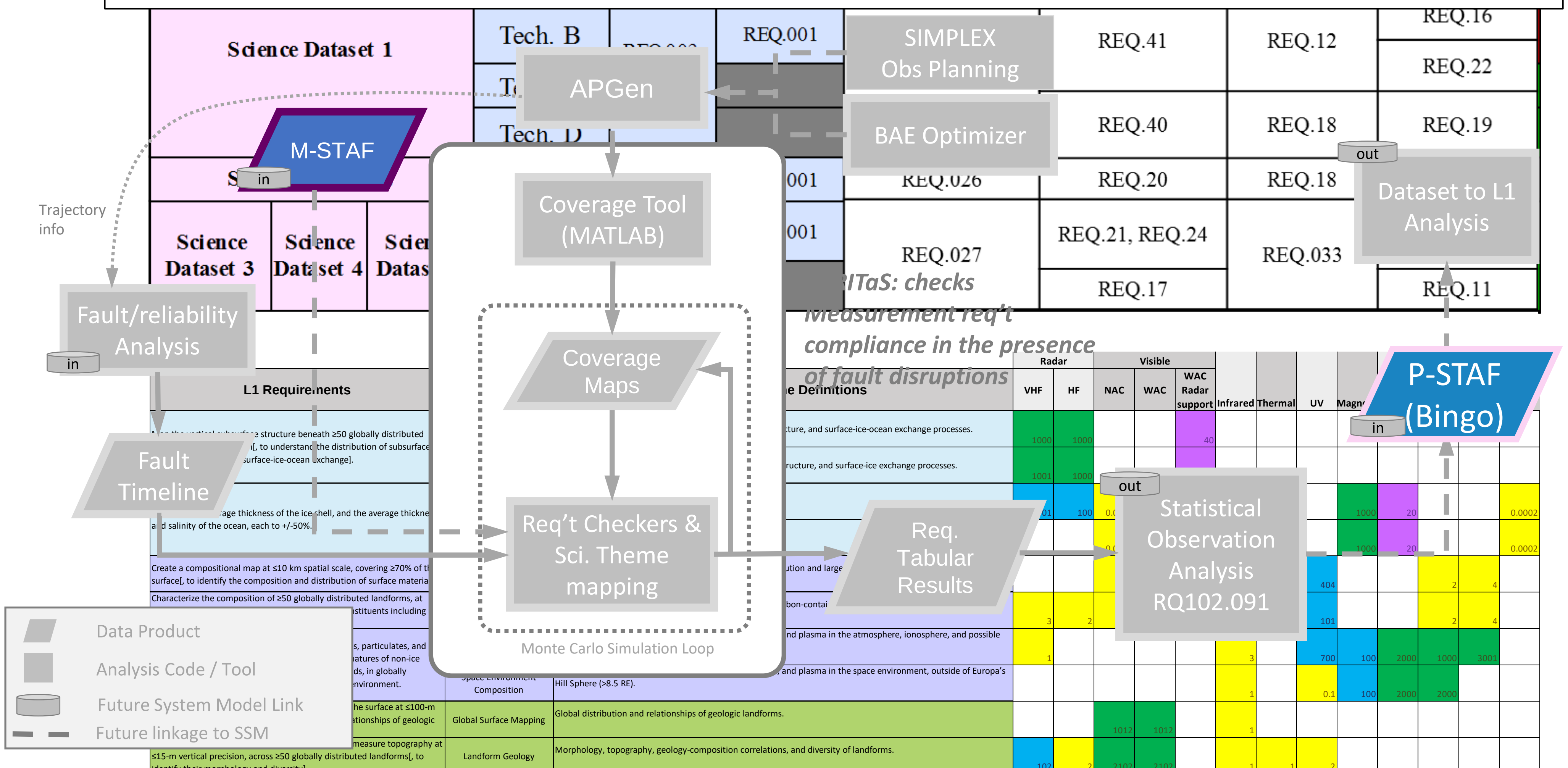
Assessment of Impacts at the Project Level



Science Sensitivity and Robustness Analysis

Assess Mission Robustness: *preserve science given potential disruptions*

- Are the science objectives met for a given tour in a faulted scenario?
- How long does the tour need to be to meet science objectives?
- What observations are at risk of being lost?
- Are spacecraft and/or instrument recovery time requirements needed?

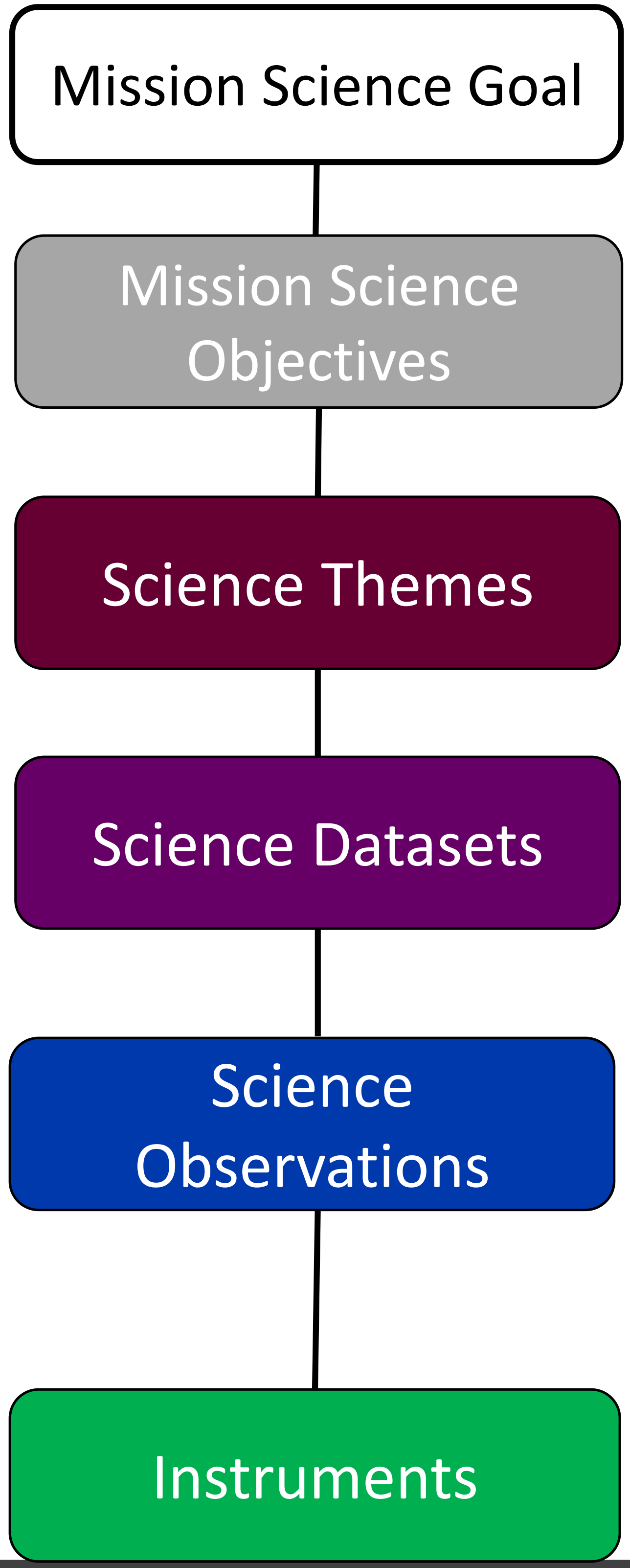


What's the (~)scope of each L1?

How much data/energy does each L1 need?

Conclusions

- STAF is divided into:
  - Project domain P-STAF
  - Measurement domain M-STAF
- STAF provides ways to achieve:
  - Traceability
  - Completeness
  - Consistency across instruments
- STAF provides efficiency in:
  - Tour analysis
  - Mission robustness analysis



Questions?

EXTRA material

STAF Taxonomy in a Nutshell

Mission Science Goal

Mission Science Objectives

Science Campaigns

[Science Scale] + [Science Target] + [Purpose/Objective]

e.g. Global-Scale Surface Composition

Science Datasets

[Science Theme] + [Measurement Class]

e.g. Global-Scale Surface Composition Ultraviolet Dataset

Science Observations

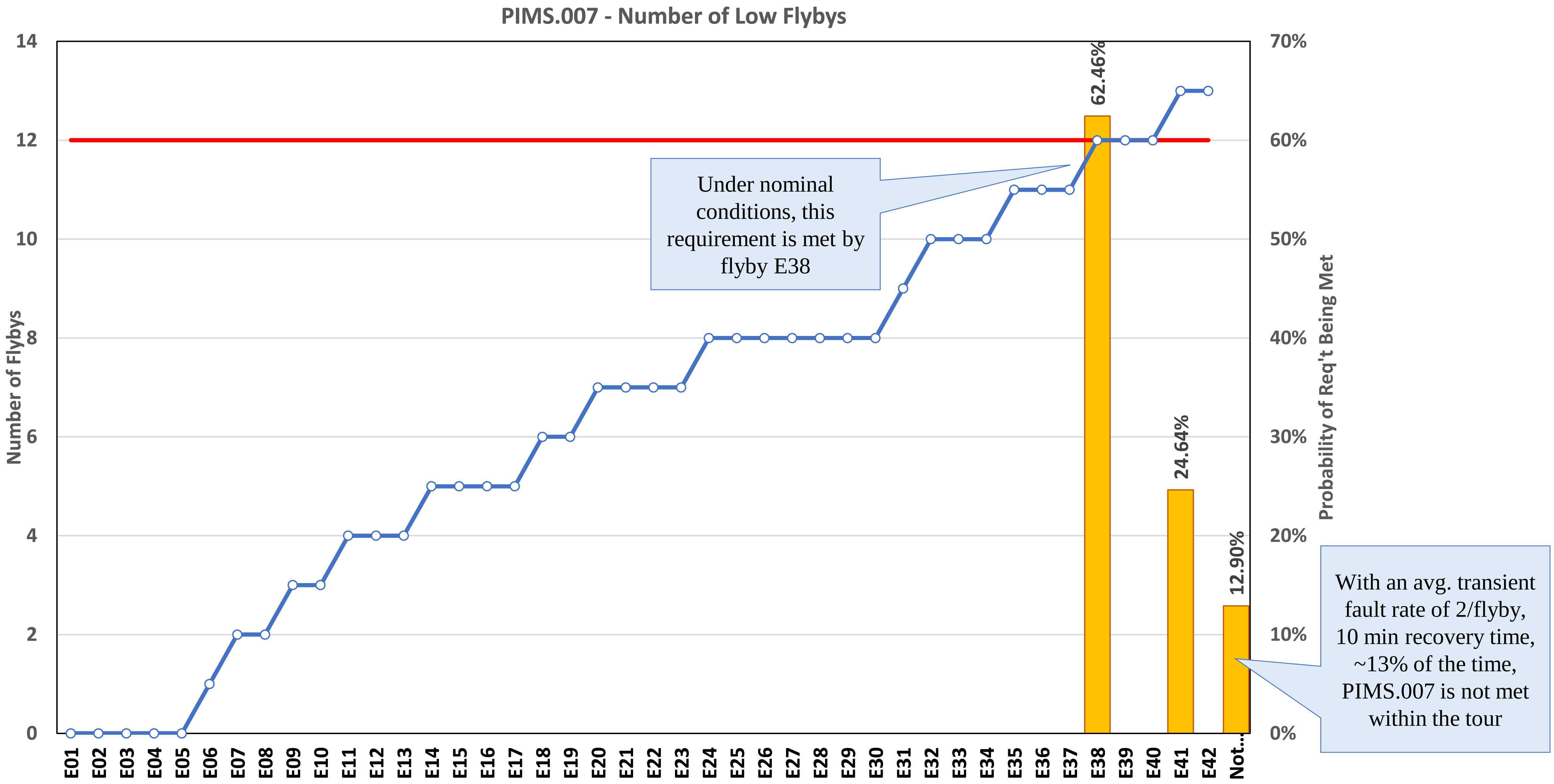
[Condition] + [Measurement Technique]

e.g. Dayside surface aurora/airglow observations

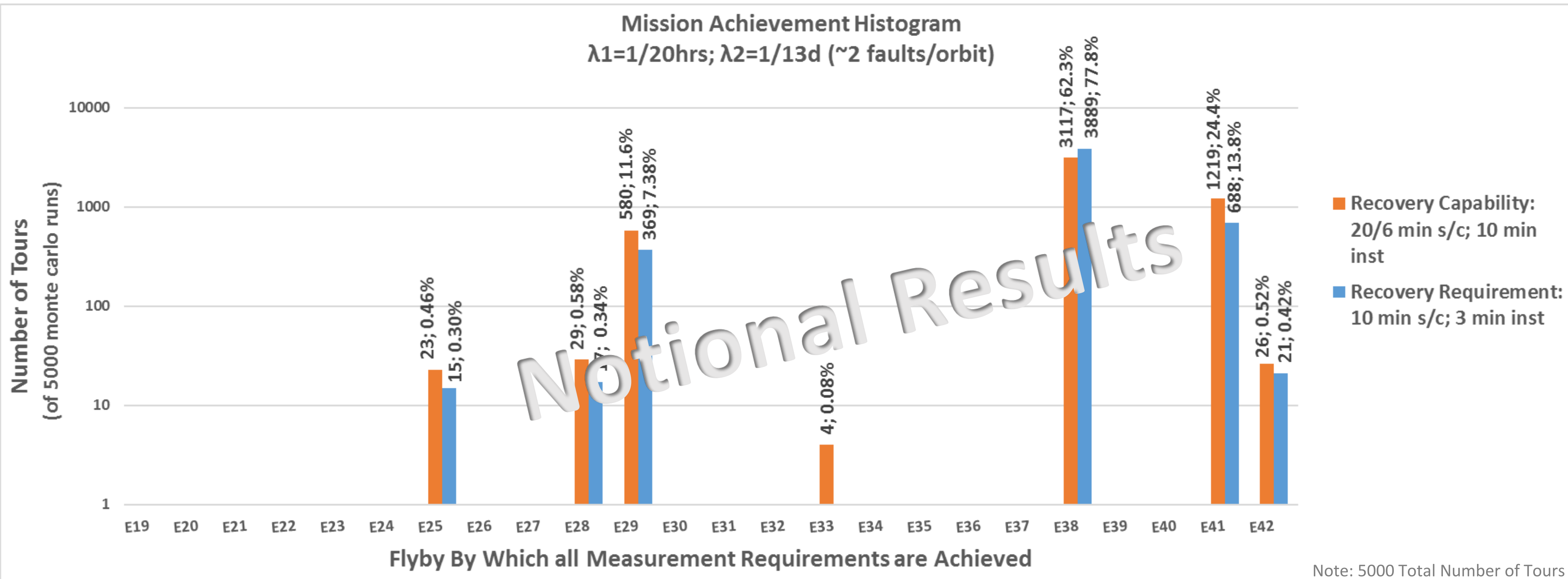
Stellar Occultations

Instruments

Requirement Robustness to Transient Faults



Mission Achieved by Flyby …



We can understand margin in the tour and the likelihood of achieving science objectives, given a s/c and instrument recovery time